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PERFORMANCE OF THE COSITE ANALYSIS MODEL (COSAM) FOR SELECTED HF EQUIPMENTS

IIT Research Institute
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Predictions using the Cosite Analysis Model (COSAM), developed by the DoD Electromagnetic Compatibility Analysis Center (ECAC), were compared with measurements of numerous interactions at a typical cosite installation. The tests involved AM and SSB equipments operating in the 2-30 MHz HF range. Measured data are provided.

Twenty-five frequency assignments were tested, each with several desired-signal levels. The types of interactions compared included

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adjacent signals, spurious responses, spurious emissions, and receiver and transmitter intermodulation.

PREFACE

The Electromagnetic Compatibility Analysis Center (ECAC) is a Department of Defense facility, established to provide advice and assistance on electromagnetic compatibility matters to the Secretary of Defense, the Joint Chiefs of Staff, the military departments and other DoD components. The center, located at North Severn, Annapolis, Maryland 21402, is under executive control of the Office of the Secretary of Defense, Director of Telecommunications and Command and Control Systems and the Chairman, Joint Chiefs of Staff, or their designees, who jointly provide policy guidance, assign projects, and establish priorities. ECAC functions under the direction of the Secretary of the Air Force and the management and technical direction of the Center are provided by military and civil service personnel. The technical operations function is provided through an Air Force sponsored contract with the IIT Research Institute (IITRI).

This report was prepared as part of AF Project 649E under Contract F-19628-76-C-0017 by the staff of the IIT Research Institute at the Department of Defense Electromagnetic Compatibility Analysis Center.

To the extent possible, all abbreviations and symbols used in this report are taken from American Standard Y10.19 (1967) "Units Used in Electrical Science and Electrical Engineering" issued by the United States of America Standards Institute.

Users of this report are invited to submit comments which would be useful in revising or adding to this material to the Director, ECAC, North Severn, Annapolis, Maryland 21402, Attention ACL.

EXECUTIVE SUMMARY

This report compares the predictions from an analytical model (COSAM), designed to evaluate the performance of a group of collocated voice communications transmitters and receivers, with measurements taken at Fort Huachuca. The measured data are included in the report and can be of value to the EMC community.

The field deployment consisted of six closely spaced antennas, six HF transmitter and receiver pairs and two antenna couplers. Twenty-five frequency assignments were used; desired signals at several levels were injected and output (S + N)/N and (S + I + N)/(I + N) (termed SINAD ratios) were measured. Coupling measurements were also taken among the antenna systems over the 2-30 MHz frequency range.

The equipment models were based on previously measured spectrum signatures, with one exception. One receiver, for which no measured data were available, was modeled using theoretical techniques. Results obtained relative to this receiver were approximately the same as those obtained relative to the other receivers employed.

Several comparisons between measurements and predictions are reported. Adjacent-signal, spurious-response, spurious-emission, and transmitter and receiver intermodulation (IM) interactions were examined. The results of the exercise indicate that COSAM is a useful engineering tool that can be employed to predict cosite interactions in a large number of cases involving commonly used HF equipment.

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INTRODUCTION

BACKGROUND

COSAM is a cosite analysis model designed to evaluate interactions between communications equipment in a statistical manner.[1] COSAM predictions are based on statistical characterizations of equipment parameters derived from measured data taken in accordance with MIL-STD-449 ( ) and theoretical considerations. These data are found, for the most part, in spectrum signature reports. These characteristics include transmitter intermodulation and other transmitter spurious emissions, receiver intermodulation, spurious responses and adjacent signals. The adjacent-signal characteristics include effects of such things as crossmodulation, desensitization and transmitter noise. The major components of a COSAM analysis are:

1. the computerized file, which contains the statistics, mentioned above, representing the transmitters and receivers,
2. spatial deployment of antennas,
3. frequency assignment,
4. RF selectivity of each antenna system,
5. antenna-to-antenna coupling,
6. the system analysis models, which combine the provided information and estimate the system performance, a probabilistic determination.

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[1] Lustgarten, M., *COSAM (Co-Site Analysis Model)*, IITRI, ECAC, Proceedings of the IEEE Symposium on EMC, July 1970.

Cosite coupling between HF antennas, especially horizontally polarized antennas, required the inclusion of an additional term in the model. Therefore, COSAM as described in APPENDIX C differs with COSAM as described in References 1 through 4. These references describe COSAM as applied to the VHF and UHF frequency bands. The first phase of COSAM development dealt primarily with conventional UHF-AM(225-400 MHz) transmitter/receiver systems that employ single channel voice modulation. The validation of that portion of the model was documented.[2,3]

The second development phase dealt with single-channel and multiplexed (30-76 MHz) VHF-FM transmitter/receiver systems. The validation for that portion of the model was also documented.[4]

A third development phase that included single-channel voice communications was a logical extension because it appeared that many of the findings of the previous efforts would be applicable to equipment using the 2-30 MHz portion of the spectrum and AM SSB and DSB modulation types.

Further, previous efforts were limited to equipment for which spectrum signatures had been available. As part of the HF effort, one receiver for which no previous measured data was available was included to demonstrate a theoretical capability to model equipment

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[2]Lustgarten, M., and Hughes, D., *Validation of the Co-Site Analysis Model (COSAM) for Selected UHF AM Equipments,* ESD-TR-71-356, ECAC, Annapolis, MD, December 1971, DDC No. AD-892-5451.

[3]Lustgarten, M., and Hughes, D., *Co-Site Analysis Model (COSAM) Validation,* IITRI, ECAC, Proceedings of the IEEE Symposium on EMC, July, 1972.

[4]Lustgarten, M., and Hughes, D., *Validation of the Co-Site Analysis, Model (COSAM) for Selected VHF-FM Equipments,* ESD-TR-73-016, ECAC, Annapolis, MD, July 1973, DDC No. AD-912583.

characteristics. Finally, the 2-30 MHz band encompasses more than three octaves, whereas previous studies considered equipments whose tuning ranges involved approximately one octave.

As in the VHF and UHF cases documented previously, no measured data were available on 3-signal HF receiver IM interactions, so that, for this type of interaction, results obtained represent a test of the capability to estimate performance with no measurements.

The major thrust is directed toward an overall system modeling capability. It is necessary to identify the parameters that appear to be most significant.

The primary measured data with which COSAM predictions are compared are the SINAD values at the receiver outputs. [The term SINAD represents the signal-plus-interference-plus-noise to interference-plus-noise ratio, or (S + I + N)/(I + N) where S refers to the desired-signal power, I is the effective sum of all interference and distortion effects and N refers to noise]. The summation is made in watts; the result is expressed in dB. A second set of data provided the coupling losses between each pair of antenna systems (including effects of any antenna matching networks). These were made by replacing transmitters by frequency-sweep generators and replacing receivers by spectrum analyzers. Coupling losses were provided for the entire HF band. Where matching networks were in the path, these measurements were repeated after retuning these to two additional frequencies. This coupling data was employed to evaluate the performance of the combined COSAM antenna coupling models and matching unit models.

OBJECTIVES

The primary objective of this study was to perform a comparison of measured data and predictions made by the COSAM program when it

is applied to a cosite environment containing commonly used HF communications equipment.

A secondary objective was to identify any parameters and interactions for which modeling refinements would result in significant improvements in performance.

APPROACH

The major findings of the measurement program were compared with COSAM predictions. Several measures were used to indicate how well the analysis results compared with the measurements.

Two measures were provided to compare predicted System Performance Scores (SPS) with measured SINAD values. The first, was the "Bin Method," applicable to overall results, which provides a confidence level in terms of SPS. SPS, for this report, is defined as the probability of exceeding a SINAD of 10 dB. Thus, if the model predictions were accurate and ten cases were noted where the predicted SPS were 0.7 then seven of these would have measured SINAD values greater than 10 dB. The "Bin Method" of comparison involves placing each case into one of several bins (or groupings). Each bin would then contain cases having approximately the same predicted SPS. The average predicted value of cases in each bin is then compared with "measured SPS" for the group in that bin. The measured SPS is the number of cases in that bin for which the measured SINAD exceeded 10 dB, divided by the total number of cases in that bin.

A second measure, the "Interference Condition Method," was also used to compare the measured SINAD values with predicted SPS values for all interactions and identifiable mechanisms noted above. The

measure provides a confidence level in terms of the magnitude of the error relative to a five-condition scale that is based on operational degradation considerations.

The overall model bias and the associated standard deviation were also computed. Model bias is defined as the average value of the differences between the measured SINAD output values and the associated predicted mean values. It was determined that, in most cases, the cause of the interactions could be identified as being due, primarily, to a specific mechanism, that is, to adjacent-signal, noise, two-or three-signal intermodulation (2nd, 3rd, 5th,and 7th orders), receiver spurious-response, or transmitter spurious-emission effects. Bias and associated standard deviation values were calculated for data groups corresponding to each mechanism. The small number of interactions that could not be specifically identified were discussed and possible future approaches to these problems were examined.

Measured coupling data were compared with predictions of the COSAM coupling model. The average difference between the measured and predicted mean values was noted; the standard deviation (σ) of the differences was calculated. Values of means and standard deviations were obtained from several sets of data.

APPENDIX A contains a detailed description of the measurement procedures and a tabulation of the measured data considered in the analysis. APPENDIX B contains a detailed description of the analysis used in the comparison of predicted and measured values. APPENDIX C is a brief description of COSAM. APPENDIX D contains a description of the procedure and theory behind the modeling of the R-388 receiver. APPENDIX E is a brief explanation of the BC-939-B coupler model and the technique used to derive it.

SECTION 2

ANALYSIS

INTRODUCTION

This section contains an outline of the measurement program and a description of the methods employed to design the experiment. The various ways of comparing measurements and predictions are also described. Finally, major results of the comparisons are provided.

MEASUREMENT PROGRAM

Both bench-test and field-test measurements were performed. The field tests included, as separate exercises, measurements of power coupling loss for a specific configuration of six closely spaced HF antennas, and a comprehensive compilation of information was obtained when each of six receivers was individually exposed to simultaneous electromagnetic radiations from five transmitters operating at various frequencies in the 3-30 MHz band.

Bench-test measurements were made on receiver sensitivity and receiver dynamic range for the two double-sideband AM receivers (the R-388 and the R-392/URR) and the two single sideband AM receivers (the RT-662/GRC and the RT-698/ARC-102).[5] Receiver adjacent-signal interference measurements were also made on the RT-698/ARC-102 receiver.

A detailed description of the field measurements is contained in APPENDIX A. Twenty-five frequency assignments were provided to

[5]Stevenson, F., *HF Cosite Analysis* (ECAC Support Task 45X3) Publication No. USAEPG-FR-721, February 1973, DDC No. AD-907881L.

the measurement agency. The six transmitters and six receivers were assigned to seven antennas. For each assignment, a specified tone-modulated desired signal was inserted into the first receiver and the output (S+N)/N ratio was noted. The five interfering transmitters were activated, using noise modulation. The output (S+I+N)/(I+N) ratio (called SINAD), was recorded for that assignment. The transmitters were turned on and off during particular tests to determine which of them contributed to the observed interference.

For several tests, the desired signal was modulated with a voice message and the undesired transmitters were modulated with a different voice message. A tape recording was then made.

This procedure was repeated for the other five receivers for the first assignment and then re-run for the other 24 assignments. Then, the entire procedure was repeated for different desired signal levels.

In effect, a total of 450 receiver measurements was called for initially [6 receivers, 25 assignments and 3 desired-signal levels (-75, -85, -95 dBm)]. However, due to high ambient noise levels 93 measurements were not made; therefore, the total number of measurements actually recorded was 357.

TABLE B-1 in APPENDIX B contains a summary of the relevant measured data, including the identification of interactions, the desired-signal level, the output (S+N)/N ratio and the output SINAD ratio. Other pertinent data, including the power levels of the various transmitters and the identification of transmitters causing significant interactions, are given in APPENDIX A.

PREDICTION PROGRAM

The predictions were made using COSAM after obtaining the measured data. The arrangement of antennas was originally intended to resemble an Army or Marine Corps tactical command post or a Navy ship antenna configuration, but practical considerations resulted in the configuration described in APPENDIX A.

Of more importance was the pattern of frequency assignments. It was deemed desirable to subject each equipment to an equal number of each of the interactions considered by COSAM, namely: adjacent signals, spurious emissions, spurious responses, and transmitter and receiver intermodulation (IM). Further it was desired to check both two- and three-signal IM mixes of various orders. Various frequency-separation ranges were included for each interaction type.

It would also have been desirable to obtain output SINAD values, ranging from zero to the maximum, in an approximately uniform distribution, for all nomenclatures. Later sections will describe the spreads involved and the number of interactions of each type.

TABLE B-1, APPENDIX B, contains, for each interaction, the desired-signal level, the predicted values of mean SINAD output, and the System Performance Score (SPS). These scores were used, as discussed below, to provide a measure of confidence for the model.

The interaction descriptions provided in TABLE B-1 refer only to the major mechanisms predicted by COSAM. In many cases, SPS values are influenced by more than one mechanism and more than one transmitter. Consequently, even though, for example, an adjacent

signal or a spurious emission is identified, the score may reflect the effects of other transmitters and other mechanisms.

MODEL COMPARISON

Evaluation of Coupling Predictions

As noted in APPENDIX A, coupling measurements were made among the six antennas. Two of the antennas were connected to the BC-939-B antenna couplers. Three tuned frequencies were used in conjunction with three tuning positions of the BC-939-B couplers. The coupling measurements and the predictions were compared,[6] resulting in the information in TABLE 1.

TABLE 1

COMPARISON OF MEASURED AND PREDICTED COUPLING LOSS VALUES

Data Set	Bias(dB)[b]	σ(dB)	Number of Samples
All cases	9.4	13.7	3,100 (approx.)
All cases within one octave	0.8	10.4	1,169
All cases within one octave, excluding antenna 4c[a]	0.2	9.0	885

[a]Terminal 4 coupler tuned to 16.2275 MHz.
[b]Bias is defined as the predicted value minus the measured value.

As can be seen, coupling loss for out-of-band cases (i.e., frequency separations involving more than one octave) tended to be

[6]Lustgarten, M., Maiuzzo, M., Martin, J. and Schneider, S., *Proposed Extension of the COSAM Co-Site Coupling Model (HF and VHF Antenna Configurations)*, ECAC-TN-75-017, August 1975.

greater than corresponding measured values; too much loss was predicted. Also, standard deviations were much larger.

A review of specific paths indicated relatively small bias values for most combinations that did not involve couplers. The mean antenna gains used in the coupling-loss calculations were -1.5 dBi for the whip and +0.5 dBi for the horizontal dipoles.

A standard deviation of approximately 6 dB or less can be expected for the antenna-to-antenna coupling model (so called "matched" coupling), for most configurations.[7] The uncertainties involved in coupler effects can be expected to increase this value to at least 9 dB, which was the lowest computed standard deviation.

In general, the bias and σ values were smaller when the tuned frequencies of each terminal were within an octave of each other than when the separations exceeded an octave. For situations involving the coupler, predictions involving large frequency separations generally were larger than measured values.

When the coupling loss measurements and predictions involving terminal 4c, which was tuned to 16.2275 MHz, were compared, the discrepancies were quite large. As a result it was decided to take a sample of those cases involving frequency separations less than one octave and a subset of these cases which excluded terminal 4c. The result is noted in TABLE 1.

Some improvement in the HF coupler model for the BC-939-B needs to be achieved outside of the band encompassing the tuned frequency

[7]Madison, J., *Extension of Co-Site Coupling Model for Communication Analysis*, ECAC-TN-71-30, October 1971.

plus or minus one octave, especially at unwanted resonant and anti-resonance frequencies. Further research is required to determine realistic impedance values for transmitters, receivers, couplers, and antennas in order to obtain improved agreement between coupler-model predictions and measurements.

Evaluation of SINAD Predictions

Three hundred fifty seven SINAD values were measured. Forty two of these were on the R-388, a thirty-band receiver for which no spectrum signature information was available. Theoretical modeling of this receiver was performed for seven bands, so that SINAD predictions for 30 of the 42 measured values could be made. This was considered sufficient for the purposes of this study. Thus, in total, 345 SINAD distributions were predicted and compared with a corresponding number of measured SINAD values. Each measurement represents one point in each predicted distribution.

An objective of this effort was to ascertain how well the predicted distributions represent the measured values. This is a relatively unusual problem in statistical analysis. Instead of having one distribution to analyze, there is a family of distributions (see APPENDIX C). The methods applied in the following subsections were developed in Reference 2.

The model bias (B in dB) is defined as follows:

$$B = \frac{1}{N} \sum_{i=1}^{N} \Delta i, \text{ dB} \tag{1}$$

where

Δi = the ith value of S_M minus the ith value of $\bar{S}_P$, in dB

S_M = the measured output SINAD value, in dB

$\bar{S}_P$ = the predicted output SINAD mean value, in dB

N = the number of samples

Therefore, B represents the average difference between the measured values and the associated predicted mean values, in dB. A positive value will indicate, on the average, that the model is predicting too much interference. A value close to zero would be desirable.

The second test performed was the computation of σ (Δ), defined as follows:

$$\sigma\ (\Delta) = \left[\sum_{i=1}^{N} (B - \Delta_1)^2/N\right]^{\frac{1}{2}} \tag{2}$$

The term σ (Δ) is the biased standard deviation of the S_M - $\bar{S}_P$ distribution and it provides a measure of the spread of the deviations from the mean. A plot of the cumulative distribution is given in Figure 1. Examination of the plot provides the percentage of the total which is less than any specified dB level.

The values of B and σ (Δ), discussed below, for all of the measurements and the various interaction categories, provide partial validation measures. In a sense, they represent the confidence one can place in the model's ability to predict mean values.

A third test was employed to determine the characteristics of $\sigma(S_P)$, the standard deviation of the predicted distribution relative

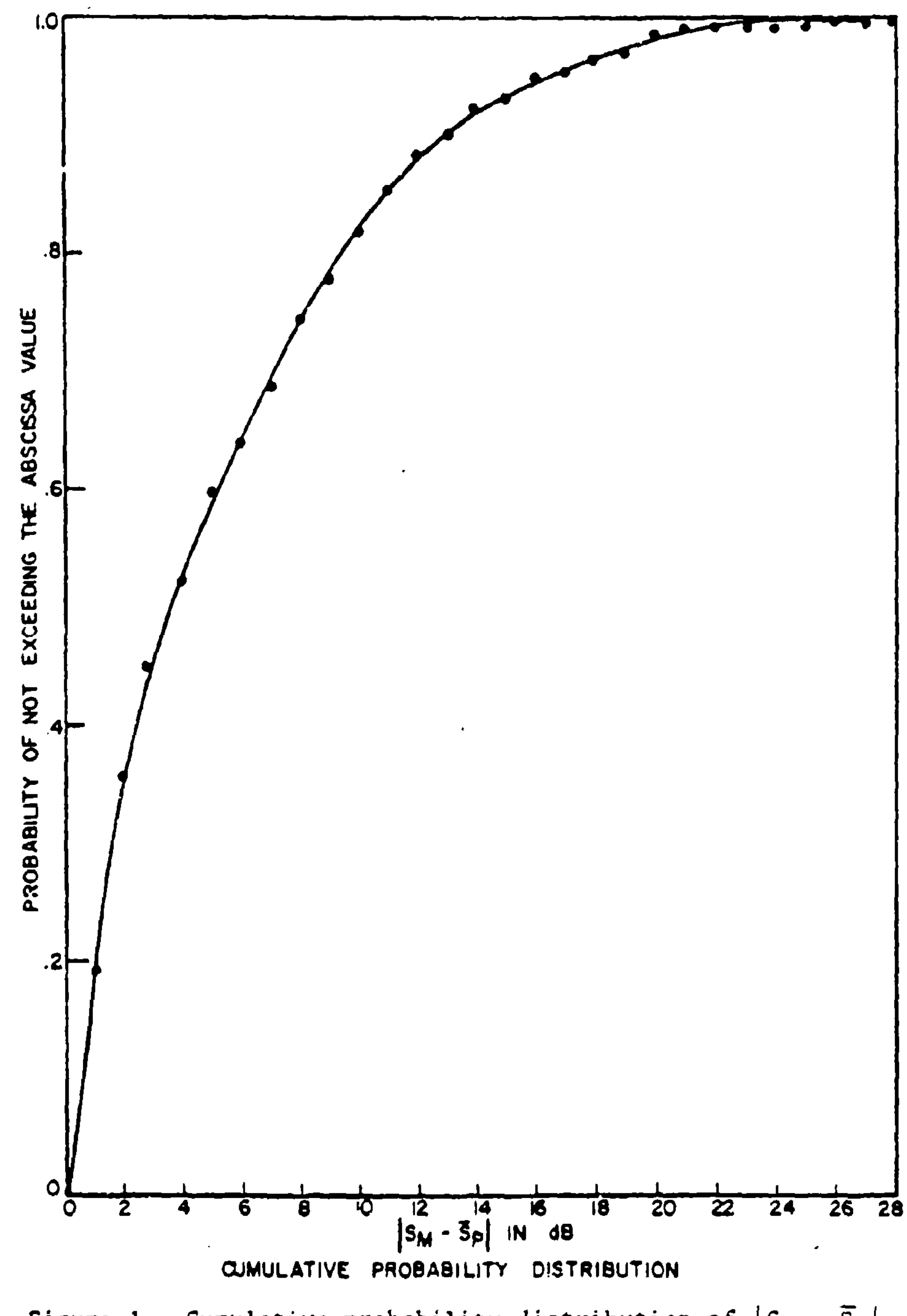


Figure 1. Cumulative probability distribution of $|S_M - \bar{S}_p|$.

to the absolute value of $S_M - \overline{S}_P$. A cumulative plot of the relationship is given in APPENDIX B, Figure B-2.

Evaluation of System Performance Score (SPS) Predictions

COSAM's primary output is a numerical estimate of operational performance. That is, the SPS is the probability of exceeding a specific SINAD threshold value (10 dB, in this study), which is relatable to an Articulation Score (AS) or an Articulation Index (AI) value. In other words, the predicted probability distribution is merely a means to an end. If possible one would prefer to have a straight-forward mathematical measure of the quality of the SPS scores, as compared to the measured SINAD values. Two approaches to this problem were adopted, namely the Bin Method and the Interference Condition Method.

The Bin Method. All of the SPS values were placed in bins, or groupings. Several bin sizes were examined. Thirteen bins were adopted since this value provides an approximately equal number of scores in each bin, except for the end points. TABLE 2 indicates the number of cases in each bin, N, and the average SPS value associated with each bin, $\overline{SPS}$, together with the percentage of total cases per bin.

Also provided is the number of cases for each bin for which the measured SINAD values exceed the threshold of 10 dB, N_T. Then, SPS_m is defined as the quotient of N_T/N.

TABLE 2

RESULTS OF COMPARISON OF PREDICTED SPS VALUES AND MEASURED SINAD VALUES (THE BIN METHOD)

Predicted SPS Limits	Number of Cases (N)	Percent of Total	$\overline{SPS}$ [a]	N_T [b]	SPS_m [c]	$SPS_m - \overline{SPS}$
.00	133	38.55	.00	24	.18	.18
.01	9	2.61	.01	1	.11	.10
.02	14	4.06	.02	1	.07	.05
.03-.05	9	2.61	.04	3	.33	.29
.06-.17	20	5.80	.11	5	.25	.14
.18-.27	16	4.64	.23	3	.19	-.04
.28-.39	18	5.22	.32	6	.33	.01
.40-.60	19	5.51	.49	9	.47	-.02
.61-.77	18	5.22	.68	11	.61	-.07
.78-.89	17	4.93	.85	11	.65	-.20
.90-.97	15	4.35	.94	13	.87	-.04
.98-.99	19	5.51	.99	10	.53	-.46
1.00	38	11.01	1.00	28	.74	-.26

[a] $\overline{SPS}$ is the average predicted SPS for the cases in that bin.

[b] N_T is the number of measured samples equaling or exceeding a SINAD value of 10 dB.

[c] SPS_m is defined as N_T/N, the effective measured SPS value.

The first and last bin are considerably larger than the others. This was because a large number of predictions were either zero (strong interference) or 1.0 (no interference), accounting for approximately 50% of the total.

The last column, $SPS_m - \overline{SPS}$, represents another possible measure. The average value of the differences was approximately -0.02 suggesting that, on the average, predicted SPS values will be too low by this amount.

Figure 2 is a plot of $\overline{SPS}$ versus SPS_m. The diagonal line describes the results an ideal model would provide. That is, since the SPS represents the probability of exceeding 10 dB, then by definition SPS should equal N_T/N.

A measure of model error, in terms of SPS units, can be obtained by subtracting the values of SPS_m from the corresponding values of SPS on the idealized curve. At the lower values of SPS, there was a tendency to predict too much interference, while at the midrange and higher values, the converse was true.

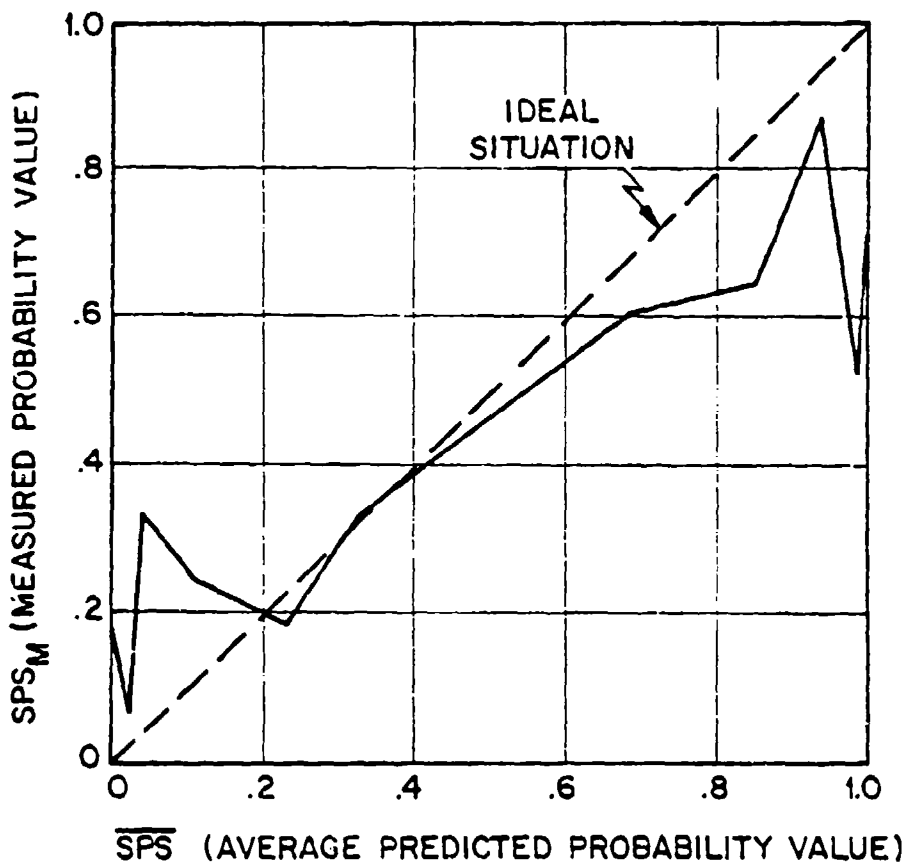


Figure 2. Comparison of measured and predicted SPS binned values.

Figure 3, a cumulative probability distribution of errors (13 values), as defined, is constructed of data from the previous figure and TABLE 2. The ordinate probability values refer to the percentage of total cases (345) for which a specified error was noted. The smoothed curve provides an estimate of model error. As can be seen, for 90% of the cases, an error of approximately 0.27 SPS units was noted. If other confidence levels are required, they may be taken from Figure 3. The smoothed curve in Figure 3 was determined by the method of multiple regression analysis using the data points.

Interference Condition Method. The Bin method provides a measure of overall error. It was also deemed desirable to provide a more detailed measure which could be applied to each type of interaction as well as to the overall population.

The Interference Condition Method is based on the hypothesis that a comparison of each measured value with each associated predicted SPS value is valid if viewed in operational terms. For example, if the SPS is 0.9 and the measured SINAD is 20 dB, one would note that this is a good prediction. Similarly, if the SINAD were 0 dB for the same SPS, one would say that this is a poor prediction. This type of decision is not entirely subjective, because limits have been specified between good and poor predictions. Past experience in rating interference conditions provides some precedent for employing this type of measure of prediction accuracy (References 2, 3, and 4).

In simple terms, it should be apparent to the COSAM user that an SPS greater than 0.8, for example, represents a low probability

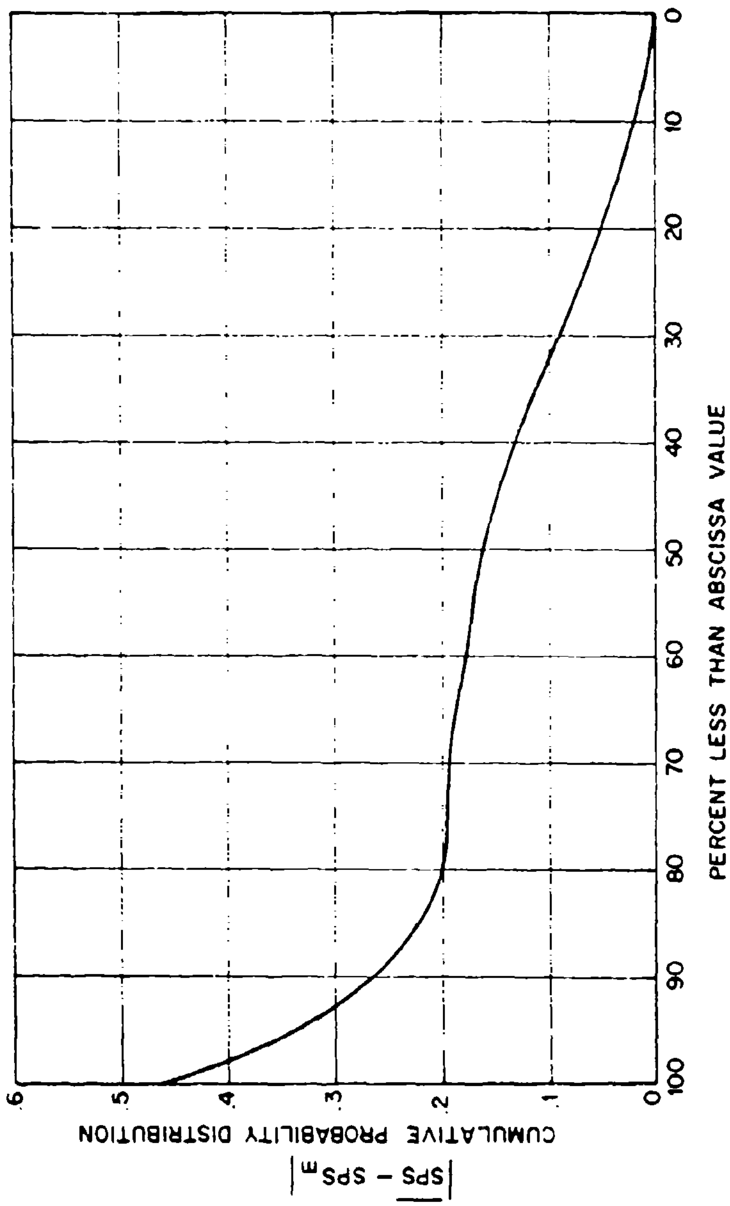


Figure 3. Cumulative probability distribution of $|SPS - SPS_M|$.

of poor performance. Similarly, scores less than 0.2 should represent a low probability of good performance, while the range between 0.4 and 0.6 represents a marginal situation. Whether 0.3 should be considered poor or marginal is a more tenuous decision.

The measured SINAD values present a similar problem in interpretation. This subject was discussed extensively in Reference 2. It is suggested that SINAD output values greater than 18 dB for military equipments are good, values between 12 dB and 18 dB acceptable, 4-12 dB marginal and values less than 4 dB poor. Other choices are possible.[a]

Labeling ranges of SPS and SINAD in such a manner will permit one to compare COSAM SPS outputs with measured values. We wish to know, primarily, the likelihood of COSAM predictions resulting in gross errors. (A gross error is defined as a prediction of good performance when a measurement indicates intolerable degradation or poor performance, or the converse situation.)

The 5-condition scale of TABLE 3 will be used to relate SPS and SINAD to operational degradation. The SPS range values in TABLE 3 were arbitrarily selected for the five conditions. The other columns in the table indicate SINAD and articulation score ranges that roughly correspond.

Since the data includes 345 pairs of SPS/SINAD values, we may simply note the percentage which have no errors, 1-condition errors, 2-condition errors, 3-condition errors, and the maximum possible error of 4 conditions.

[a] For example, the CCIR (Vol. III, 1963) indicated that 6 dB was just acceptable for operator-to-operator service, 15 dB was marginal for commercial use, and 33 dB was good for commercial use.

TABLE 3

SPS/SINAD FIVE-CONDITION SCALE

Condition	SPS Range	SINAD Range (dB)	Articulation Score Range
A	0.81-1.00	> 18	> 0.85
B	0.61-0.80	> 12; ≤ 18	0.75-0.85
C	0.41-0.60	> 7; ≤ 12	0.65-0.75
D	0.21-0.40	> 4; ≤ 7	0.5-0.65
E	0.00-0.20	≤ 4	< 0.5

The 5-condition scale is quite suitable for this exercise since it will account for minor score or measurement differences. A 1-condition error would, presumably, be acceptable. A 2-condition error might be undesirable but still acceptable. (This assumuption is discussed in more detail below.) A 3-condition error would be poor and a 4-condition error would be clearly unacceptable. We consider 3- and 4-condition errors to be gross errors.

Before proceeding to an analysis of the data, we note the relationships between possible condition errors and SINAD dB differences. That is, if there is an X dB difference between a predicted and measured SINAD value, what is the impact in terms of condition errors?

For each receiver the maximum SINAD predicted was limited by the upper value of the receiver dynamic range.

TABLE 4 indicates that a difference less than or equal to 7 dB will not result in three- or four-condition errors. Differences less than 10-12 dB will occasionally result in three-condition errors

and a minimum difference of 14 dB is required to cause a four-condition error. In the extreme, even a 26 dB difference may result in only a three-condition error.

TABLE 4

SINAD dB DIFFERENCE VS CONDITION ERROR RANGE (FIVE CONDITION SCALE)

dB Difference $[\lvert S_m - \overline{S}_p \rvert]$	Condition Error Range	
	Minimum	Maximum
>26	4	4
22-26	3	4
18-22	2	4
14-18	1	4
12-14	1	3
7-12	0	3
4-7	0	2
0-4	0	1

We will define our interference condition confidence levels, p_{1c} and p_{2c}, as the probability of not experiencing an error of more than 1 or 2 conditions, respectively. APPENDIX B contains detailed data, including probabilities of not experiencing a condition error and experiencing one-, two-, three-, and four-condition errors, as well as a discussion of the implications of dB differences.

SUMMARY OF RESULTS

This sub-section outlines the results of the analysis. Validation measures for all interactions, as well as the results obtained

for some of the individual interactions, are noted. APPENDIX B provides an expanded discussion of the findings, particularly with respect to intermodulation (IM) effects.

TABLE 5 provides the computed values of B, $\sigma(\Delta)$ and p_{2c} defined above. Note the distinction between adjacent-signal and noise interactions. If no other interaction is noted, the effects are said to be due to noise. Numerous potential spurious responses, spurious emissions and IM interactions were found to be primarily due to noise and, in most cases, were predicted accordingly.

Three types of interaction conditions are of interest, namely:

1. predicted and noted
2. predicted but not noted
3. noted but not predicted.

These conditions are particularly applicable to spurious responses, spurious emissions and intermodulation. No spurious responses or emissions were placed in the "noted but not predicted" category, although it is possible that some of the adjacent-signal cases were due to these interactions. APPENDIX B discusses each interaction in detail emphasizing those cases which involved gross errors.

A review of the numerical values in TABLE 5 indicates the following:

1. The bias value (B) for all 345 interactions was -.54 dB.
2. For the individual interactions (excluding transmitter IM) bias value magnitudes were all less than 1.6 dB.

TABLE 5

SUMMARY OF MAJOR RESULTS

Interaction Types	B(dB)	σ(Δ)(dB)	P_{2c}	Number of Cases	% Cases
All Interactions	- .54	7.60	.87	345	100.0
Adjacent Signal	-1.09	7.74	.87	135	39.1
Noise	- .23	3.37	1.00	48	13.9
Spurious Responses	1.60	8.10	.84	19	5.5
Predicted and Noted	1.21	8.76	.83	12	3.5
Predicted But Not Noted	2.27	6.78	.86	7	2.0
Spurious Emissions	-1.63	6.74	.87	23	6.7
Predicted and Noted	-1.28	7.05	.83	18	5.2
Predicted But Not Noted	-2.88	5.28	1.00	5	1.4
All Receiver Intermodulation	-1.08	8.39	.84	107	31.0
2-Signal RIM	-2.23	8.76	.79	57	15.7
Predicted and Noted	4.70	5.06	.92	13	3.8
Predicted But Not Noted	6.98	5.73	.86	7	2.0
Noted But Not Predicted	-6.41	7.26	.73	37	10.7
3-Signal RIM	- .23	7.73	.90	50	14.5
Predicted and Noted	4.46	5.45	1.00	8	2.3
Predicted But Not Noted	5.16	5.07	.89	18	5.2
Noted But Not Predicted	-4.89	7.13	.88	24	7.0
Transmitter Intermodulation	7.27	5.96	.62	13	3.8
Predicted and Noted	7.07	6.49	.71	7	2.0
Predicted But Not Noted	7.50	5.26	.50	6	1.7

3. $\sigma(\Delta)$ values were all less than 9 dB. These variations were due, in large part, to coupling prediction errors.

4. The P_{2c} values for the major interactions, i.e., adjacent signal, spurious responses, etc., were greater than or equal to .84 for about 96% of the cases. For all interactions, P_{2c} was .87. P_{1c}, involving zero or one-condition errors was 0.71 for all interactions.

The P_{2c} measures provide coarse indications of confidence levels. The values are of interest also in that they may be used to compare results obtained in previous exercises. A more detailed review of the measured data, however, indicates that approximately 100 cases occurred that involved (S+N)/N values (with no interference present) less than 12 dB. For these cases, it was not possible to obtain an error greater than two conditions. If these cases are omitted, P_{2c} is approximately 0.8.

Consequently, the P_{2c} measure of 0.87, relating to all of the samples, is not too meaningful and will not be specified as being the estimate of model confidence. If a dB measure of confidence is desired, APPENDIX B indicates that 82% of the cases resulted in SINAD differences of less than 10 dB between the measurements and the predicted mean values. Note, however, in TABLE 4, that a 10-dB error will not always result in a gross error.

An additional calculation was made to estimate the probability of what might be termed Type I gross errors. That is, what is the probability that the model will predict good performance when, in fact, intolerably poor performance will result?

The assumption was made that SPS values of 0.9 or greater imply good performance and that SINAD values of 4 dB or less imply unacceptable performance. In 15% of these cases, SPS predictions of 0.9 or greater resulted in SINAD values of 4 dB or less. Stated another way, a confidence level of 85% can be assigned to the assertion that a Type I gross error will not occur.

Type II gross errors, involving the converse situation of predicting poor performance when good performance will occur, were calculated by assuming that only cases involving $(S+N)/N \geq 18$ dB would be applicable. Of these, the cases involving SPS scores ≤ 0.1 and SINAD values ≥ 18 dB were said to constitute Type II errors. Nine percent of these cases resulted in errors, as defined. Consequently, a confidence level of 91% can be assigned to the assertion that a Type II gross error will not occur.

It is of interest to note that the Type I gross errors were *all* due to four IM interactions. Three of the four involved terminal #4, at which coupling errors were significantly larger than average. Two of the interactions were due to 3-signal, 3rd-order mixes, one of which is predicted by COSAM and one of which is not. Errors due to the first interaction were caused by overestimating coupling loss. The other two interactions, also not predicted by COSAM, could not be identified. It appears that they may have been caused by spurious emissions or responses in conjunction with an IM mix.

The Type II errors were due to two interactions, one ascribed to an adjacent-signal mechanism and the other to a 2-signal, 5th-order IM product. These prediction errors were caused by underestimating coupling loss. Note that a 3-dB error in coupling loss could account for a 15-dB error in a 5th-order IM interaction.

DISCUSSION

APPENDIX B provides a summary of additional data and associated evaluations. This section presents a few brief highlights of the study. In general, scores less than 0.2 are indicative of probable intolerable degradation. Scores between 0.2 and 0.6 are indicative of marginal performance. If values less than 0.6 appear, they should be treated as requiring attention. The user can, in general, be confident that scores greater than 0.9 require no further attention. Ideally, all scores should be greater than this value.

The user is warned that, occasionally, spurious responses and emissions will not be properly evaluated by COSAM. Some could be predicted and not noted; some will be noted but not predicted.

In regard to intermodulation, evaluation of the measured data revealed 12 assignments where IM was predicted but did not appear. A significant number of apparent 2-signal (34) and 3-signal (27) interactions occurred that were not predicted. Type I errors are due primarily to this situation. Some of the latter represent cases which are not presently included in COSAM, but which are being considered for addition to the model on the basis of their frequency of occurrence and probable impact.

As indicated in APPENDIX B, the most significant coupling-loss error involved the prediction of rejection due to coupler characteristics when frequency separations exceeded one octave. Mismatch losses at wide frequency separations also presented difficulties when no coupler was present.

These coupler or "coupling" prediction problems undoubtedly influenced prediction of IM as well as spurious responses and emissions. The IM problem is particularly difficult because an error in coupling loss is effectively multiplied by the *order* of the IM interaction. It is not, therefore, surprising that larger errors are encountered for higher order IM cases.

It is difficult to determine for any particular IM case whether the major error was due to the IM model or the coupling model. More effort in this important area is needed.

In an operational situation, most of the cases will be either obviously acceptable or obviously unacceptable. Considerable effort was required to generate assignments whose SINAD outputs fell between 5 and 12 dB, corresponding to SPS values between 0.2 and 0.6, approximately. As indicated in APPENDIX B, only 28% of the total cases were in this range. In an operational situation, an even smaller percentage of marginal values can be expected.

In other words, most of the scores will probably be greater than 0.6 or less than 0.2. If scores of 0.9 or greater are achieved, as is recommended, the chance of a gross error will be approximately 15% or, in betting parlance, about six-to-one odds.

Most of the situations involved predictions based on knowledge of responses of receivers to standarized tests specified in MIL-STD-499 ( ) and reported in spectrum signatures. One receiver, the R-388 at terminal 2, lacked such information. Responses of this receiver were predicted based on theoretical modeling techniques described in APPENDIX D. It is of interest, therefore, to examine

the predictions involving this equipment. As indicated in TABLE D-1, APPENDIX D, 90% of the SINAD errors were less than 10 dB. In addition, P_{1c} and P_{2c} were 73.3% and 96.7% respectively. These results were better than average, indicating that the theoretical techniques employed were quite successful.

CONCLUDING COMMENTS

The measurement program appears to have achieved its primary purpose, namely, to act as a basis for comparison with the HF models integrated into COSAM. However, additional effort to improve the model's capability to predict situations involving frequency separations exceeding an octave, and to include IM interactions not presently considered, is desirable.

This report and the earlier reports (References 2 and 4), particularly APPENDIX A of each, represent a test bed for those who either have or are developing a cosite analysis capability. The data can be used as a basis for comparison with any model of this type. The results of such a validation can be used to rate the model and compare it to COSAM's performance, if desired.

SECTION 3

RESULTS AND MAJOR FINDINGS

RESULTS

The major results, in terms of agreement between measurements and predictions, were as follows:

1. The Bin Method of evaluating SPS predictions, depicted in Figure 3, indicates there is 90% confidence that a measured value, SPS_m, will lie within the interval of predicted SPS $\pm$ 0.27.

2. The Interference Condition Method of evaluating SPS predictions (using a five-condition scale) indicates that COSAM results were within one condition of measured results for 71% of the cases, and within two conditions for 87% of the cases. The probability of gross errors is approximately 0.15 if a score of 0.9 or greater is obtained. [A gross error is defined as the prediction of acceptable or better performance when a measurement indicates intolerable degradation (less than 4 dB SINAD), or the converse situation.]

3. In 82% of the cases, the differences between measured and mean predicted SINAD values was less than 10 dB (See Figure 1).

4. The model bias for 345 SINAD distribution predictions was -0.5 dB, (prediction of too little interference). The standard deviation was 7.6 dB.

5. An evaluation of the interactions identified as being due to specific mechanisms (adjacent signals, spurious emissions and responses, and intermodulation) indicated that, for 96% of the cases, the bias magnitude for each mechanism was less than 1.7 dB,

and the standard deviations for all cases were less than 9 dB (see TABLE 5).

6. A comparison of measured coupling values and associated predicted mean values (excluding cases involving frequency separations greater than one octave, and terminal 4c when its antenna coupler was tuned to 16 MHz) resulted in a bias (B) of 0.2 dB with a standard deviation (σ) of 9.0 dB for 885 samples. With terminal 4c included (a total of 1169 samples), B was 0.8 and σ was 10.8. When separations of more than an octave were included (total of approximately 3000 samples) B was 9.4 dB and σ was 13.7 dB.

MAJOR FINDINGS

The results presented above and in Section 2 provide an estimate of the performance to be expected from an HF cosite analysis employing COSAM. A more detailed comparison was also made, pointing primarily to two factors which contributed to differences between COSAM predictions and the measured data. One of these is the lack of consideration of every possible interaction; this caused the erroneous prediction of no interference in some cases.

From a practical standpoint, it seems unlikely that a model could be constructed that considers every possible interaction at sites where there are large numbers of HF transmitters and receivers. However, certain high-order IM interactions, including those of even order, appear to be significant in HF environments, whereas they are not significant in the VHF and UHF ranges. A significant number of apparent two- and three-signal interactions occurred that were not predicted because they have not been programmed in COSAM. In

a smaller number of cases, IM was predicted but did not appear. (This was believed to be due to coupling prediction errors.)

The other primary factor involves errors in coupling predictions. Errors in coupling loss estimates can have a multiple effect on accuracy. In addition to the direct effect, intermodulation (IM) power levels tend to be proportional to the order of the product. For example, in third-order IM, a 10 dB bias error in coupling would result in a 30 dB IM level error. An examination of the coupling data indicated that the BC-939-B coupler model, for frequency separations greater than one octave, resulted in a large coupling-loss prediction-error bias.

In addition, some spurious responses and emissions were not properly evaluated by COSAM; some were predicted but not noted and others were noted but not predicted. In general, the results of the exercise indicate that COSAM is a useful engineering tool that can be employed to predict cosite interactions in a large number of cases involving commonly used equipment.

APPENDIX A

DESCRIPTION OF FIELD MEASUREMENTS

INTRODUCTION

This appendix contains much of the material provided in Reference 5. It is repeated here for the following reasons:

1. The referenced document may not be readily obtainable.
2. Its availability provides authentication of the validation process described in this document.
3. It furnishes the basis for any agency to perform its own model validation of all or part of the total test.

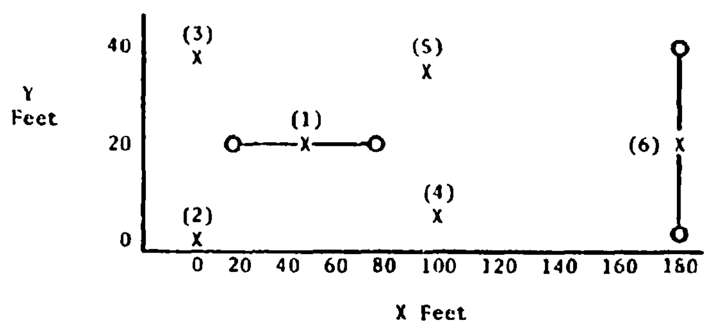
DISCUSSION OF CONTENTS

Figures A-1 and A-2 represent the antenna and system configurations used. The equipment at positions 1 and 4 consisted of two RT-698/ARC-102 transceivers; the unit at terminal 1 was connected to a half wave horizontal dipole, while the equipment at terminal 4 was coupled, via the BC-939-B coupler, to a 15-foot whip antenna. A large van was used to house the R-388 receiver and T-368/URT transmitter for terminal 2, with the 15-foot whip antenna mounted on top of the vehicle. Another BC-939-B coupler was connected between the transmitter and the antenna.

Terminals 3 and 6 both used RT-662/GRC and AM-3349/GRC-106 equipments. The only difference was that the antenna at terminal 3 was a jeep-mounted 15-foot whip, while the antenna for position 6

Terminal Number	Antenna Characteristics
	Antenna Description
1	Horizontal halfwave dipoles cut for 16.3185 MHz and 23.9600 MHz, with RF Cable Assembly CG-557 A/U and AN/GRC-26D AR-115/U masts
2,3,4,5	Vertical whip (vehicular) - mast sections MS-49 through MS-53 and base section MP-47A P/O AN/GRC-26
6	Horizontal halfwave dipoles cut for 11.9985 MHz and 24.7500 MHz, with RF Cable Assembly CG-557 A/U and AN/GRC-26D AR-155/U masts
	Antenna Mounting
1,6	Mast mounted
2	Mounted on a modified M-119 van near the top, rear, and center
3,5	Mounted on a jeep frame
4	Mounted on a wood stake to simulate a manpack configuration
	Antenna Terminal Coordinates (feet)[a]

Terminal Number	X	Y	Z
1	50.0	20.0	32.71
2	0.0	0.0	11.65
3	0.0	40.0	1.90
4	100.0	5.0	1.38
5	100.0	35.0	1.96
6	180.0	20.0	36.29



[a]For dipoles, coordinates are for the dipole center. Heights (Z) are to the base of the whips and to the center connectors of the dipoles.

Figure A-1. Antenna description and orientation.

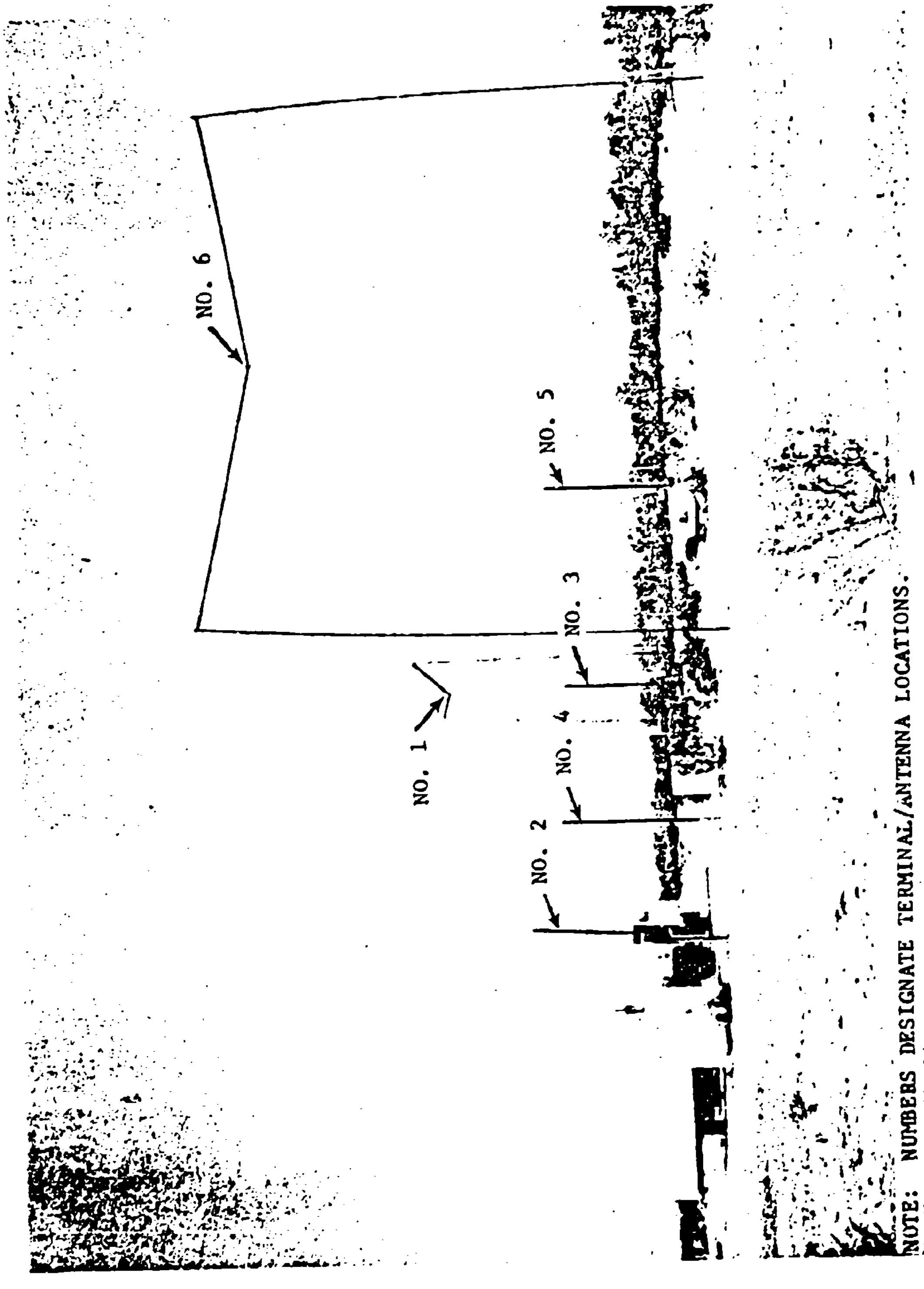


Figure A-2. Overall field configuration.

was a horizontal half-wave dipole. Terminal 5 was identical to 3 except that R-392/URR and T-195/GRC-19 equipments were used. The van adjacent to the one used for terminal 2 housed the measurement instrumentation and the test link transmitter (TLT).

Several types of field measurements were performed. One, called "coupling," consisted of driving each antenna system (including couplers where present) with a 50-ohm signal generator (one at a time) and measuring power at the output of every other antenna system. Another, termed "system performance," consisted of setting up 25 frequency assignments and measuring the SINAD ratio at each receiver output. Other measurements performed included impedance measurements at transmitter outputs, coupler inputs, coupler outputs, and antenna terminals. Equivalent transfer impedance (see KTM, Reference 8) of the coupler was also measured.[8,9] The COSAM system will accept such measured data for use in the overall prediction proces . For some reason not fully understood, much better results were obtained employing theoretically derived models for coupler and antenna impedances. Measured transmitter impedance values were not used for the coupling model validation (Reference 6). Instead, a figure of fifty ohms was used for all transmitter and receiver impedances.

The system performance predictions were made in a similar manner. The setup for terminal 2 was somewhat different, however. The transmitting antenna was in the same location as in the coupling

[8]Martin, R. L., *Transmitter/Receiver, Antenna, Coupler, Evaluator (TRACE)*, ECAC-TN-72-21, December 1972.

[9]Martin, R. L., *Modification to Transmitter/Receiver, Antenna, Coupler Evaluator (TRACE)*, ECAC-TN-72-21-1, November 1973.

measurements. The receiving antenna employed (not shown) was located on the front (opposite end) of the van. The coupler was employed only in the transmit mode.

COUPLING TEST DESCRIPTION

Figure A-3 is a representative sample of the coupling data taken between all antenna pairs at their respective tuned frequencies. For further data, the original document (Reference 5) should be obtained. Cosite coupling measurements were taken over the entire band by means of a frequency sweeping technique.

The technique involved recording the amplitude of the received power levels (throughout the frequency range) on a spectrum analyzer. Given appropriate calibration and the known input power, coupling loss could be read directly from photographs of the analyzer display.

SYSTEM PERFORMANCE TEST DESCRIPTION

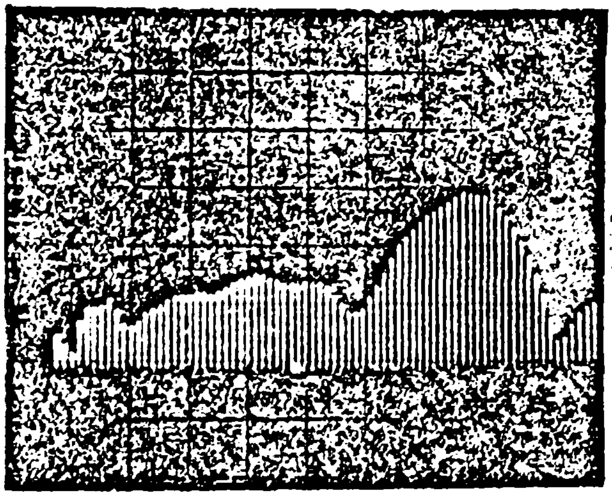
TABLE A-1 represents the 25 frequency assignments used in the system performance test. An audio tape has been prepared which contains typical interference conditions of different levels due to the various phenomena encountered.

TABLES A-3 through A-27 indicate the (S+N+D)/(N+D) and (S+I+N+D)/(I+N+D) values for the desired signal levels with all of the interferers on and with only a subset activated.

The six receiver/transmitter combinations were tuned to the designated frequencies for frequency assignment I, as given in TABLE A-1. Each transmitter was modulated with speech-shaped noise

COSITE COUPLING

LOG REFERENCE (dBm): 0



CENTER FREQUENCY (MHz): 10

PHOTOGRAPH NO. 33

TRANSMITTER

ANTENNA POSITION: 1
COUPLER FREQ. (MHz): N/A

RECEIVER

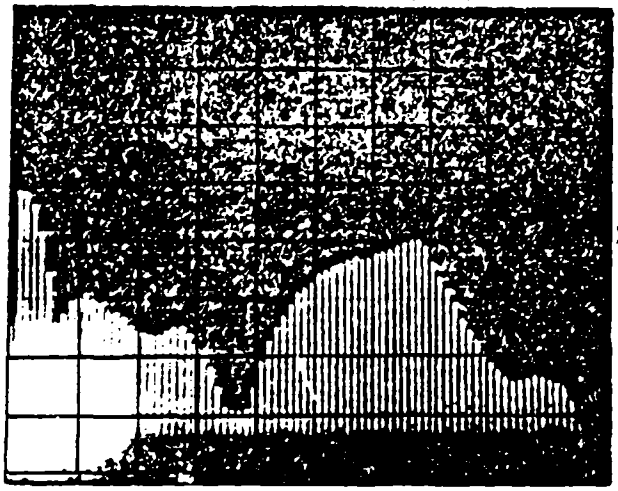
ANTENNA POSITION: 5
COUPLER FREQ. (MHz): N/A

BANDWIDTH (kHz): 10

SWEEPWIDTH (MHz/div): 2

SCAN TIME(s/div): 2

LOG REFERENCE (dBm): 0



CENTER FREQUENCY (MHz): 40

PHOTOGRAPH NO. 34

TRANSMITTER

ANTENNA POSITION: 1
COUPLER FREQ. (MHz): N/A

RECEIVER

ANTENNA POSITION: 5
COUPLER FREQ. (MHz): N/A

BANDWIDTH (kHz): 10

SWEEPWIDTH (MHz/div): 5

SCAN TIME (s/div): 2

Figure A-3. Example of COSITE coupling measurements.

TABLE A-1

EQUIPMENT RADIO FREQUENCY MATRICES, FREQUENCIES IN MHz

Frequency Assignment Number	Terminal Number 1	2	3	4	5	6
	Equipment					
	RT-698/ARC-102	R-388 T-368/URT	RT-662/GRC AM-3349/GRC-106	RT-698/ARC-102	R-392/URR T-195/GRC-19	RT-662/GRC AM-3349/GRC-106
I	16.320	8.172	17.500	5.822	5.233	12.246
II	16.320	5.852	27.950	4.610	5.233	11.628
III	16.387	5.852	17.500	16.078	11.630	12.246
IV	16.385	9.124	25.400	7.360	3.196	12.088
V	16.320	4.840	24.140	8.160	5.301	12.069
VI	16.082	4.021	9.124	8.182	5.257	12.069
VII	16.320	8.160	24.460	9.121	12.250	12.002
VIII	16.318	5.822	23.910	16.082	5.882	23.710
IX	16.387	5.882	24.460	17.458	5.433	24.130
X	16.078	5.301	25.390	5.882	17.458	23.910
XI	16.078	4.520	25.560	3.195	4.962	24.860
XII	16.322	3.175	17.462	4.886	5.882	24.460
XIII	16.082	8.059	17.462	12.088	4.027	24.210
XIV	16.387	17.481	29.965	8.058	4.612	23.740
XV	16.082	3.175	29.905	5.850	11.696	25.700
XVI	16.082	3.197	4.610	5.431	4.018	25.700
XVII	16.078	12.088	5.304	7.358	8.160	24.940
XVIII	16.387	5.848	27.600	17.478	5.301	24.940
XIX	16.320	7.360	25.560	17.500	4.563	24.920
XX	23.710	11.628	4.840	8.171	12.088	24.210
XXI	23.740	17.481	4.962	8.160	3.197	24.870
XXII	23.740	16.385	17.462	7.358	9.121	25.390
XXIII	24.130	4.022	3.343	4.563	9.121	25.560
XXIV	24.130	4.022	27.770	4.642	5.882	25.450
XXV	24.210	4.019	27.750	5.205	4.612	25.390

for 100 percent AM or peak envelope power (PEP) in the upper sideband (USB) mode, as appropriate. The transmitters were tuned to produce maximum power into the antenna system. The power output into a 50-ohm system was measured.

Terminal number 1 equipment was placed in the receive mode. Transmitters at the other five terminals were placed in the standby mode. The TLT was modulated with a 1,000-Hz tone to produce PEP or 30 percent AM, as appropriate. The link attenuation was adjusted to provide a desired signal level of -95 dBm at the test link receiver (TLR) input. The TLR antenna was connected to the TLR, and a measurement of (S+N+D)/(N+D) was made at the receiver output.

The other five transmitter-interferers were activated and a SINAD measurement was made at the TLR output. Selected combinations of interferers were activated and associated SINAD measurements were made at the TLR output to determine which interferers were the major contributors to the desired signal degradation. Generally, data were recorded for only those selected interferer combinations which produced 5 dB or more degradation with respect to the (S+N+D)/(N+D) measurement.

The measurements were repeated with the receiver at each of the other five terminals and for the remaining desired signal levels of -85 and -75 dBm while the TLR and the remaining five terminals were activated.

The desired signal levels of -95 dBm, -85 dBm, and -75 dBm were used except when the -95 dBm level could not produce a 10-dB (S+N+D)/(N+D) receiver output because of high ambient interference.

For those cases, the desired signal level was increased until a 10-dB (S+N+D)/(N+D) ratio was achieved. This level of desired signal determined the number of 10 dB increments of desired signal which were used for SINAD ratio degradation measurements. In assignment XXI (TABLE A-23), relative to TLR number 1, the first desired signal level which produced a 10-dB (S+N+D)/(N+D) was -93 dBm and the next two levels of desired signal were -83 and -73 dBm.

A total of 25 combinations representing 450 individual measurements of (S+I+N)/(I+N) was planned; however, not all frequencies could be used because of outside interference. Intermittent interference, from unknown sources, made several additional frequencies unusable during certain tests.

Voice message degradation data in the form of an audio tape recording were obtained for selected frequency assignment, receiver terminal number, desired signal level, and interferer combinations. These combinations are given in TABLE A-2. The TLT, TLR, and interferers were tuned to the designated frequencies for frequency assignment II as given in TABLE A-2. The transmitters at interferer terminal numbers 2 and 5 were modulated with a standard voice message for 100 percent AM or PEP, USB as appropriate. The interferers were adjusted to produce maximum output power.

The TLT was modulated with a different standard voice message for 100 percent AM or PEP, USB as appropriate. The link attenuation was adjusted to provide -85 dBm at the TLR, terminal 4, input. A tape recording of the TLR audio output (which was 45 seconds in length) was obtained.

TABLE A-2

VOICE MESSAGE DEGRADATION PARAMETERS

Frequency Assignment Number	Receiver Terminal Number	Desired Signal (dBm)	Interferer Terminal Numbers	(S+N+D)/(N+D) (dB)	SINAD (dB)
II	4	-85	2,5	18	3
II	4	-75	2.5	18	8
II	5	-75	2	20	4
III	4	-95	1	17	1
III	4	-85	1	21	1
V	3	-75	6	27	6
XI	3	-85	6	18	2
XI	3	-75	6	23	5
XI	3	-85	4	18	11
XI	3	-75	4	23	19
XVI	2	-88	3,4,5	10	2
XVI	2	-78	3,4,5	13	2
XVII	2	-88	3	10	3
XVII	2	-78	3	17	8
XVII	2	-68	3	17	14
XVII	4	-88	5	10	3
XVII	4	-78	5	18	3
XVII	4	-68	5	20	14
XXIV	5	-75	2,4	10	4

The TLR output was recorded on tape channel number 2 and appropriately annotated for run number, receiver number, desired signal level, SINAD ratio, and interferer combinations. A simultaneous clear-channel recording of the TLT input was made on channel number 1.

The voice message degradation test was repeated for each of the other 18 parameter combinations given in TABLE A-2.

TEST RESULTS

Values of (S+I+N)/(I+N), and interferer power levels are given in TABLES A-3 through A-27.

An apparent anomaly was noted in a few cases where interference was less with all interferers on than with only one interferer on (the worst-case values are recorded in TABLE B-1 and used for this analysis). This phenomenon was confirmed by multiple checks, and therefore is believed to represent the true situation, although the explanation is not known.

TABLE A-3

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT I

Terminal No./Transmitter Power (watts)					
1/140	2/450	3/120	4/120	5/140	6/140
Test Link Receiver				**Interferer**	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	a	11	1	3 2, 6	1 1
2	d				
3	d				
4	a	11	3	2 1, 5, 6	4 3
5	d				
6	d				

[a] Desired signal level -95 dBm

1	b	20	2	3 2, 6	2 2
2	-78	10	5	1, 6	5
3	b	10	3	4 1, 2, 5	2 4
4	b	17	10	2 1, 5, 6	14 10
5	d				
6	d				

[b] Desired signal level -85 dBm

1	c	25	5	3 2, 6	6 5
2	-68	14	10	1, 6	10
3	c	19	9	4 1, 2, 5	5 10
4	c	18	16	None	None
5	-55	10	1	4, 6 3, 4, 6	4 [illegible]
6	c	10	5	1, 2 4, 5	5 3

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-4

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT II

Terminal No./Transmitter Power (watts)					
1/115	2/400	3/60	4/120	5/132	6/110

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	$\frac{(S+N+D)}{(N+D)}$ (dB)	$\frac{(S+I+N+D)}{(I+N+D)}$ (dB) Five Active Interferers	Selected Terminal Combinations	Related $\frac{(S+I+N+D)}{(I+N+D)}$ (dB)
1	d				
2	d				
3	a	22	22	None	None
4	a	17	1	1, 2 2, 5	11 1
5	a	19	3	1 2	14 3
6	d				

[a]Desired signal level -95 dBm

1	d				
2	d				
3	b	22	22	None	None
4	b	18	3	1, 2 2, 5	14 3
5	b	20	3	1 2	15 4
6	d				

[b]Desired signal level -85 dBm

1	-67	10	10	None	None
2	-67	10	1	1, 5 4, 5	2 1
3	c	22	22	None	None
4	c	18	8	2, 5	8
5	c	20	4	1 2	15 4
6	-60	10	10	None	None

[c]Desired signal level -75 dBm

[d]No data taken due to high ambient noise level

TABLE A-5

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT III

Terminal No./Transmitter Power (watts)					
1/135	2/425	3/100	4/140	5/110	6/140

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	$\frac{(S+N+D)}{(N+D)}$ (dB)	$\frac{(S+I+N+D)}{(I+N+D)}$ (dB) Five Active Interferers	Selected Terminal Combinations	Related $\frac{(S+I+N+D)}{(I+N+D)}$ (dB)
1	-90	10	1	4	1
2	d				
3	a	17	10	1	11
4	a	17	1	1 2, 6	1 1
5	-90	11	2	4 6	2 2
6	d				

[a]Desired signal level -95 dBm

1	-80	15	1	4	2
2	d				
3	b	12	11	None	None
4	b	21	1	1 2, 6	1 9
5	-80	11	2	4 6	2 2
6	d				

[b]Desired signal level -85 dBm

1	-70	15	1	4	2
2	-67	10	10	None	None
3	c	10	9	None	None
4	c	21	1	1 2, 6	4 17
5	-70	11	2	4 6	2 2
6	-67	10	6	None	None

[c]Desired signal level -75 dBm

[d]No data taken due to high ambient noise level

TABLE A-6

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT IV

Terminal No./Transmitter Power (watts)					
1/140	2/350	3/200	4/140	5/140	6/105

Test Link Receiver: Receiver Terminal Number	S (dBm)	$\frac{(S+N+D)}{(N+D)}$ (dB)	$\frac{(S+I+N+D)}{(I+N+D)}$ (dB) Five Active Interferers	Interferer: Selected Terminal Combinations	Interferer: Related $\frac{(S+I+N+D)}{(I+N+D)}$ (dB)
1	d				
2	d				
3	a	13	13	None	None
4	a	12	4	1, 3	4
5	d				
6	d				

[a]Desired signal level -95 dBm

1	d				
2	-86	10	7	None	None
3	b	15	15	None	None
4	b	23	14	1, 3	14
5	d				
6	d				

[b]Desired signal level -85 dBm

1	-55	10	10	None	None
2	-76	18	15	None	None
3	c	15	15	None	None
4	c	29	24	1, 3	24
5	c	10	1	2 4	1 1
6	c	10	10	None	None

[c]Desired signal level -75 dBm

[d]No data taken due to high ambient noise level

TABLE A-7

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT V

Terminal No./Transmitter Power (watts)					
1/140	2/240	3/140	4/140	5/130	6/105
Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	-91	10	1	4	1
2	d				
3	a	12	2	6	2
4	a	11	5	2, 6 2, 5, 6	7 5
5	d				
6	d				

[a] Desired signal level -95 dBm

1	-81	20	1	4	1
2	d				
3	b	14	3	6	3
4	b	16	10	2, 6 2, 5, 6	14 10
5	d				
6	d				

[b] Desired signal level -85 dBm

1	-71	23	1	4	1
2	-70	10	7	None	None
3	c	27	6	6	6
4	c	20	17	2, 5, 6	17
5	-70	10	0	2 4	0 0
6	-77	10	3	3	3

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-.

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT VI

Terminal No./Transmitter Power (watts)					
1/130	2/400	3/170	4/140	5/155	6/140
Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	d				
2	d				
3	a	16	2	5 2, 5	3 2
4	a	21	6	2, 6	6
5	a	11	2	4 3, 4, 6	3 2
6	a	18	6	2 3, 4, 5	10 8

[a] Desired signal level -95 dBm

1	b	10	2	2	2
2	d				
3	b	23	3	5 2, 5	10 5
4	b	22	15	2, 6	15
5	b	11	2	4 3, 4, 6	3 2
6	b	22	8	2 3, 4, 5	10 8

[b] Desired signal level -85 dBm

1	c	16	6	2	6
2	-77	10	3	1, 5	3
3	c	14	9	None	None
4	c	22	21	None	None
5	-60	11	2	4 3, 4, 6	4 2
6	c	22	14	2 3, 4, 5	14 14

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-9

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT VII

Terminal No./Transmitter Power (watts)					
1/145	2/425	3/180	4/140	5/85	6/150

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	-90	10	0	2	0
2	d				
3	a	10	7	None	None
4	a	12	5	2 5	5 6
5	a	14	3	2 4	7 3
6	d				

[a] Desired signal level -95 dBm

1	-80	17	2	2	2
2	d				
3	b	13	10	None	None
4	b	18	17	None	None
5	b	12	11	None	None
6	d				

[b] Desired signal level -85 dBm

1	-70	21	6	2	6
2	-65	10	2	1, 3	2
3	c	13	13	None	None
4	c	18	18	None	None
5	c	12	12	None	None
6	-45[e]	2	None	None	None

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level
[e] Desired signal level not increased above -45 dBm

TABLE A-10

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT VIII

Terminal No./Transmitter Power (watts)					
1/140	2/450	3/160	4/175	5/130	6/140
Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	d				
2	d				
3	-89	10	1	6	1
4	d				
5	d				
6	a	10	1	3	1

[a]Desired signal level -95 dBm

1	d				
2	-80	10	0	5	0
3	-79	19	1	6	1
4	b	10	1	1	2
5	b	10	0	2 4	0 1
6	b	18	1	3	1

[b]Desired signal level -85 dBm

1	-55	10	3	4	3
2	-70	15	0	5	0
3	-69	24	[illegible]	6	1
4	c	20	2	1	2
5	c	15	0	2 4	0 2
6	c	28	1	3	1

[c]Desired signal level -75 dBm

[d]No data taken due to high ambient noise level

TABLE A-11

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT IX

Terminal No./Transmitter Power (watts)					
1/130	2/350	3/130	4/160	5/140	6/160

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	d				
2	d				
3	-90	10	1	6	1
4	a	18	18	None	None
5	a	11	1	2 1, 2	2 1
6	a	22	1	3	1

[a] Desired signal level -95 dBm

1	d				
2	d				
3	-80	19	1	6	1
4	b	19	19	None	None
5	b	11	2	2	2
6	b	22	1	3	1

[b] Desired signal level -85 dBm

1	-70	10	10	None	None
2	-58	10	9	None	None
3	-70	27	1	6	1
4	c	19	19	None	None
5	c	11	2	2	2
6	c	22	3	3	3

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-12

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT X

Terminal No./Transmitter Power (watts): 1/140 2/430 3/140 4/130 5/70 6/150

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	d				
2	d				
3	a	10	7	None	None
4	a	21	16	2, 6	16
5	d				
6	a	14	5	3 3, 4, 5	6 5
1	d				
2	d				
3	b	19	16	None	None
4	b	21	20	None	None
5	d				
6	b	23	11	3 3, 4, 5	15 11
1	-62	10	10	None	None
2	-57	10	10	None	None
3	c	28	26	None	None
4	c	21	21	None	None
5	-55	10	2	3 2, 4, 6	3 1
6	c	31	20	3 3, 4, 5	24 21

[a] Desired signal level -95 dBm

[b] Desired signal level -85 dBm

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-13

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XI

Terminal No./Transmitter Power (watts)

1/140	2/250	3/130	4/110	5/150	6/140

Test Link Receiver: Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Interferer: Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	a	10	2	2, 3, 5	2
2	a	11	2	5	4
				1, 3, 5	2
3	a	10	2	4	4
				6	2
4	a	15	2	6	10
				2, 5	2
5	d				
6	a	10	1	3	1
1	b	18	2	2, 3, 5	2
2	b	13	2	5	8
				1, 3, 5	2
3	b	18	3	4	11
				6	2
4	b	22	3	6	20
				2, 5	3
5	d				
6	b	17	2	3	2
1	c	26	2	2, 3, 5	2
2	c	14	2	5	10
				1, 3, 5	2
3	c	23	3	4	19
				6	5
4	c	23	10	6	23
				2, 5	10
5	-69	10	2	2	4
				1, 2, 3	2
6	c	21	2	3	2

[a] Desired signal level -95 dBm

[b] Desired signal level -85 dBm

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-14

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XII

Terminal No./Transmitter Power (watts)					
1/130	2/275	3/150	4/ 120	5/150	6/135

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	a	10	2	3	2
2	d				
3	d				
4	d				
5	d				
6	a	10	4	4 3, 4	5 4

[a] Desired signal level -95 dBm

1	b	20	2	3	2
2	d				
3	-82	10	3	1 5	6 1
4	-78	10	6	None	None
5	d				
6	b	18	12	4 3, 4	13 12

[b] Desired signal level -85 dBm

1	c	25	5	3	5
2	-63	10	10	None	None
3	-72	19	5	1 5	11 2
4	-68	19	15	None	None
5	-65	10	8	None	None
6	c	22	20	4 3, 4	22 20

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-15

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XIII

Terminal No./Transmitter Power (watts)					
1/140	2/275	3/150	4/100	5/150	6/160

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	-88	10	3	2, 5	4
2	a	10	2	5	2
3	d				
4	a	12	2	5	2
5	a	11	2	3 4	5 2
6	a	12	2	2 4	3 2

[a]Desired signal level -95 dBm

1	-78	20	11	2, 5	12
2	b	16	2	5	2
3	b	10	7	None	None
4	b	18	2	5	6
5	b	12	2	3 4	11 2
6	b	19	3	2 4	8 5

[b]Desired signal level -85 dBm

1	-68	25	19	2, 5	20
2	c	14	3	5	3
3	c	18	15	None	None
4	c	22	5	5	14
5	c	12	3	3 4	12 3
6	c	22	10	2 4	14 12

[c]Desired signal level -75 dBm

[d]No data taken due to high ambient noise level

TABLE A-16

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XIV

Terminal No./Transmitter Power (watts)					
1/140	2/150	3/120	4/130	5/150	6/150

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	a	10	10	None	None
2	d				
3	a	10	6	None	None
4	a	14	10	None	None
5	a	10	1	[illegible]	[illegible]
6	a	15	15	None	None

[a]Desired signal level -95 dBm

1	b	19	17	None	None
2	d				
3	b	28	24	None	None
4	b	21	18	None	None
5	b	11	4	1, 3, 4 2, 3, 4	8 8
6	b	21	21	None	None

[b]Desired signal level -85 dBm

1	c	20	20	None	None
2	c	10	8	None	None
3	c	22	20	None	None
4	c	23	23	None	None
5	c	11	6	None	None
6	c	21	21	None	None

[c]Desired signal level -75 dBm

[d]No data taken due to high ambient noise level

TABLE A-17

OPERATIONAL SUBTEST FREQUENCY ASSIGNMENT XV

Terminal No./Transmitter Power (watts)					
1/140	2/390	3/120	4/120	5/130	6/140

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	a	10	2	4, 5, 6 2, 4, 5	4 2
2	a	10	9	None	None
3	a	10	9	None	None
4	a	20	2	2 2, 6	8 2
5	d				
6	a	15	12	None	None

[a] Desired signal level -95 dBm

1	b	16	7	4, 5, 6 2, 4, 6	11 9
2	b	17	17	None	None
3	b	18	18	None	None
4	b	22	2	2 2, 6	14 3
5	-80	10	2	1 1, 4, 6	6 3
6	b	20	19	None	None

[b] Desired signal level -85 dBm

1	c	19	16	4, 5, 6 2, 4, 6	17 16
2	c	17	17	None	None
3	c	21	21	None	None
4	c	22	4	2 2, 6	17 11
5	-70	15	4	1 1, 4, 6	8 7
6	c	21	21	None	None

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-18

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XVI

Terminal No./Transmitter Power (watts)					
1/140	2/375	3/150	4/120	5/140	6/140
Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	-90	10	2	2 3	2 5
2	-88	10	2	3, 4, 5	2
3	a	13	3	2 2, 4, 5	7 4
4	a	10	1	3 2, 3, 5	3 1
5	d				
6	a	10	10	None	None

[a] Desired signal level -95 dBm

1	-80	18	5	2 3	8 10
2	-78	13	2	3, 4, 5	2
3	b	14	8	2 2, 4, 5	12 11
4	b	18	1	3 2, 3, 5	9 1
5	b	10	2	1, 3, 4 2, 3, 4	2 2
6	b	15	15	None	None

[b] Desired signal level -85 dBm

1	-70	21	13	2 3	14 15
2	-68	14	4	3, 4, 5	2
3	c	12	12	None	None
4	c	18	1	3 2, 3, 5	16 1
5	c	11	2	1, 3, 4 2, 3, 4	8 2
6	c	17	17	None	None

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-19

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XVII

Terminal No./Transmitter Power (watts)					
1/115	2/350	3/80	4/110	5/40	6/100
Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	a	10	4	2, 3, 4, 5	4
2	-88	10	2	3	3
3	a	10	10	None	None
4	-88	10	3	5	3
5	d				
6	a	10	8	None	None

[a]Desired signal level -95 dBm

1	b	17	10	2, 3, 4, 5	14
2	-78	17	8	3	8
3	b	14	14	None	None
4	-78	18	8	5	8
5	b	10	2	1 4	5 2
6	b	16	16	None	None

[b]Desired signal level -85 dBm

1	c	22	20	2, 3, 4, 5	22
2	-68	17	14	3	14
3	c	12	12	None	None
4	-68	20	14	5	14
5	c	11	2	1 4	9 2
6	c	19	19	None	None

[c]Desired signal level -75 dBm

[d]No data taken due to high ambient noise level

TABLE A-20

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XVIII

Terminal No./Transmitter Power (watts)					
1/140	2/350	3/135	4/150	5/150	6/100

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	-89	10	8	None	None
2	d				
3	a	10	1	2	1
4	a	14	4	2, 6 5, 6	6 6
5	-87	10	1	2 4	1 2
6	a	10	7	4, 5	3

[a]Desired signal level -95 dBm

1	-79	16	14	None	None
2	-80	10	10	None	None
3	b	20	3	2	3
4	b	23	6	2, 6 5, 6	9 9
5	-77	11	1	2 4	2 3
6	b	19	16	4, 5	8

[b]Desired signal level -85 dBm

1	-69	20	19	None	None
2	-70	15	15	None	None
3	c	27	9	2	9
4	c	27	13	2, 6 5, 6	22 22
5	-67	11	2	2 4	3 7
6	c	26	24	4, 5	18

[c]Desired signal level -75 dBm

[d]No data taken due to high ambient noise level

TABLE A-21

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XIX

Terminal No./Transmitter Power (watts)					
1/145	2/350	3/140	4/180	5/150	6/130
Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	-92	10	8	None	None
2	d				
3	d				
4	a	15	2	2, 6	2
5	d				
6	a	10	1	3	1

[a]Desired signal level -93 dBm

1	-82	17	16	None	None
2	-76	10	2	3, 4	2
3	b	10	1	6	1
4	b	24	6	2, 6	6
5	b	10	1	4 2, 4	2 1
6	b	18	1	3	1

[b]Desired signal level -85 dBm

1	-72	20	19	None	None
2	-66	19	6	3, 4	6
3	c	19	1	6	1
4	c	28	14	2, 6	14
5	c	12	1	4 2, 4	4 2
6	c	26	1	3	1

[c]Desired signal level -75 dBm

[d]No data taken due to high ambient noise level

TABLE A-22

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XX

Terminal No./Transmitter Power (watts)					
1/120	2/250	3/125	4/130	5/50	6/140

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	a	11	3	6	2
2	d				
3	a	22	22	None	None
4	a	11	11	None	None
5	d				
6	-93	10	1	1 3	2 1

[a] Desired signal level -95 dBm

1	b	14	9	6	6
2	b	10	4	5	4
3	b	18	18	None	None
4	b	19	19	None	None
5	b	10	2	1, 2	2
6	-83	17	1	1 3	2 1

[b] Desired signal level -85 dBm

1	c	13	13	6	12
2	c	15	12	None	None
3	c	12	12	None	None
4	c	22	22	N[illegible]	None
5	c	11	2	1, [illegible]	2
6	-73	21	3	1 3	14 3

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-23

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XXI

Terminal No./Transmitter Power (watts)

1/120	2/200	3/135	4/130	5/140	6/140

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	-93	10	1	6	1
2	d				
3	a	18	1	4, 5	1
4	a	12	1	3, 5	3
				3, 5, 6	3
5	a	10	1	3, 4	2
				3, 4, 6	1
6	-92	10	6	3	6

[a] Desired signal level -95 dBm

1	-83	18	2	6	2
2	d				
3	b	18	3	4, 5	3
4	b	19	6	3, 5	10
				3, 5, 6	6
5	b	12	1	3, 4	2
				3, 4, 6	1
6	-82	18	15	3	15

[b] Desired signal level -85 dBm

1	-73	19	10	6	10
2	c	10	9	None	None
3	c	13	8	4, 5	9
4	c	20	13	3, 5	18
				3, 5, 6	13
5	c	12	2	3, 4	2
				3, 4, 6	2
6	c	25	25	None	None

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-24

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XXII

Terminal No./Transmitter Power (watts)					
1/120	2/300	3/50	4/135	5/150	6/140
Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	$\frac{(S+N+D)}{(N+D)}$ (dB)	$\frac{(S+I+N+D)}{(I+N+D)}$ (dB) Five Active Interferers	Selected Terminal Combinations	Related $\frac{(S+I+N+D)}{(I+N+D)}$ (dB)
1	a	10	1	2, 4	1
2	d				
3	d				
4	d				
5	d				
6	a	13	13	None	None

[a] Desired signal level -95 dBm

1	b	14	3	2, 4	4
2	-80	10	1	3 1, 4	1 1
3	-82	10	2	2	2
4	-83	10	8	None	None
5	d				
6	b	22	22	None	None

[b] Desired signal level -85 dBm

1	c	15	8	2, 4	10
2	-70	13	1	3 1, 4	1 1
3	-72	18	2	2	2
4	-73	20	17	None	None
5	-70	10	2	4 3, 4	3 2
6	c	30	30	None	None

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-25

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XXIII

Terminal No./Transmitter Power (watts)					
1/125	2/400	3/70	4/100	5/150	6/110
Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	a	10	1	2	1
2	d				
3	a	23	22	None	None
4	d				
5	d				
6	a	13	12	None	None
1	b	15	1	2	1
2	d				
3	b	18	18	None	None
4	d				
5	d				
6	b	22	21	None	None
1	c	15	1	2	1
2	-60	10	9	None	None
3	c	13	13	None	None
4	-55	10	10	None	None
5	-70	10	1	4 4, 6	2 1
6	c	31	29	None	None

[a] Desired signal level -95 dBm

[b] Desired signal level -85 dBm

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-26

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XXIV

Terminal No./Transmitter Power (watts)					
1/125	2/400	3/125	4/100	5/140	6/100
Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	a	11	1	2	1
2	d				
3	a	10	6	None	None
4	d				
5	d				
6	a	11	10	None	None

[a] Desired signal level -95 dBm

1	b	15	1	2	1
2	d				
3	b	17	13	None	None
4	d				
5	d				
6	b	20	19	None	None

[b] Desired signal level -85 dBm

1	c	15	2	2	2
2	-60	10	10	None	None
3	c	24	22	None	None
4	-68	10	7	None	None
5	c	10	4	2, 4	4
6	c	27	27	None	None

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

TABLE A-27

OPERATIONAL SUBTEST-FREQUENCY ASSIGNMENT XXV

Terminal No./Transmitter Power (watts)					
1/130	2/550	3/125	4/110	5/135	5 110

Test Link Receiver				Interferer	
Receiver Terminal Number	S (dBm)	(S+N+D)/(N+D) (dB)	(S+I+N+D)/(I+N+D) (dB) Five Active Interferers	Selected Terminal Combinations	Related (S+I+N+D)/(I+N+D) (dB)
1	a	11	2	2, 4, 6	2
2	d				
3	-92	10	4	1, 6	7
				2, 4, 6	4
4	a	15	2	1, 2	10
				1, 2, 6	2
5	a	12	2	4	6
				2, 4, 6	2
6	a	11	2	1, 2, 4	2

[a] Desired signal level -95 dBm

1	b	13	5	2, 4, 6	6
2	d				
3	-82	18	11	1, 6	13
				2, 4, 6	11
4	b	22	2	1, 2	18
				1, 2, 6	2
5	b	12	5	4	6
				2, 4, 6	5
6	b	20	6	1, 2, 4	6

[b] Desired signal level -85 dBm

1	c	13	11	2, 4, 6	12
2	-65	10	1	5	2
				4, 5	2
3	-72	22	18	1, 6	15
				2, 4, 6	19
4	c	23	3	1, 2	2[illegible]
				1, 2, 6	3
5	c	12	7	4	8
				2, 4, 6	8
6	c	24	13	1, 2, 4	13

[c] Desired signal level -75 dBm

[d] No data taken due to high ambient noise level

APPENDIX B

QUANTITATIVE COMPARISON OF PREDICTED AND MEASURED DATA

This appendix provides a summary of the measured and predicted data and a discussion of various computations performed to evaluate COSAM predictions. The following Table of Contents for this appendix is supplied for the convenience of the reader.

TABLE OF CONTENTS

MEASURED AND PREDICTED DATA

TABLE B-1 is a summary of the data obtained by field measurements, as extracted from tables supplied in APPENDIX A and associated predicted information. In the Measured Value columns, PD is the input desired signal in dBm; (S+N)/N and SINAD are the receiver output ratios, in dB, measured without and with simultaneous emissions from five transmitters, respectively.

The abbreviations employed are defined as follows:

AS: adjacent signal

SR: spurious response

SR (NF): (not found): refers to a predicted spurious response which was not noted as being a major interaction

SE: spurious emission

RIM: receiver intermodulation (3 refers to 3rd order, etc.)

TIM: transmitter intermodulation (3 refers to 3rd order, etc.)

NOISE: indicates no significant interference from any specific transmitter

$: indicates that the predicted major interaction was predicted to be below the ambient noise level, however, interference above the noise was measured.

*: indicates that the predicted major interaction was also a significant measured interaction.

The numbers in brackets refer to the predicted significant interfering transmitter. Where two numbers appear, a 2-signal mix was predicted; three numbers signify a 3-signal mix.

TABLE B-1

SUMMARY OF MEASURED AND PREDICTED DATA
(Page 1 of 4)

TEST NO.	FREQ. MHZ	MEASURED VALUES									MAJOR PREDICTED INTERACTION	PREDICTED VALUES								
		PD.	S+N/N	SINAD	PD.	S+N/N	SINAD	PD.	S+N/N	SINAD		PD.	SPS	SINAD	PD.	SPS	SINAD	PD.	SPS	SINAD
I -1	16.32	-95.	11.80	1.00	-85.	20.00	2.00	-75.	25.00	5.00	RIMS(3,4,6)	-95.	.00	.00	-85.	.00	.00	-75.	.00	.00
I -2	8.17				-78.	10.00	5.00	-68.	14.00	10.00	RIMS(1,3,4)				-78.	.00	.32	-68.	.00	.64
I -3	17.50				-85.	10.00	3.00	-75.	19.00	9.00	AS(1)				-85.	.00	2.99	-75.	.24	6.95
I -4	5.82	-95.	11.00	3.00	-85.	17.00	10.00	-75.	18.00	16.00	AS(5)	-95.	.28	9.34	-85.	.98	16.89	-75.	1.00	23.56
I -5	5.23							-55.	10.00	1.00	AS(4)							-55.	.00	.22
I -6	12.25							-75.	10.00	5.00	$SE(2)							-75.	.33	9.74
II -1	16.32							-67.	10.00	10.00	RIM2(3,6)							-67.	.00	2.03
II -2	5.85							-67.	10.00	1.00	*TIM3(4,5)							-67.	.00	.00
II -3	27.95	-95.	22.00	22.00	-85.	22.00	22.00	-75.	22.00	22.00	RIM2(1,6)	-95.	.04	3.73	-85.	.44	10.02	-75.	.90	18.37
II -4	4.61	-95.	17.00	1.00	-85.	18.00	3.00	-75.	18.00	8.00	*TIM3(2,5)	-95.	.00	.00	-85.	.00	.00	-75.	.00	.00
II -5	5.23	-95.	19.00	3.00	-85.	20.00	3.00	-75.	20.00	4.00	AS(4)	-95.	.00	.00	-85.	.00	.00	-75.	.00	.01
II -6	11.63							-60.	10.00	10.00	*NOISE							-60.	.48	10.50
III -1	16.39	-90.	10.00	1.00	-80.	15.00	1.00	-70.	15.00	1.00	*AS(4)	-90.	.00	3.55	-80.	.16	7.01	-70.	.59	11.59
III -2	5.85							-67.	10.00	10.00	*NOISE							-67.	.61	11.15
III -3	17.50	-95.	17.00	10.00	-85.	12.00	11.00	-75.	10.00	9.00	*AS(1)	-95.	.00	.85	-85.	.01	2.53	-75.	.14	5.94
III -4	16.08	-95.	17.00	1.00	-85.	21.00	1.00	-75.	21.00	1.00	*AS(1)	-95.	.02	3.42	-85.	.12	6.26	-75.	.48	10.57
III -5	11.63	-90.	11.00	2.00	-80.	11.00	2.00	-70.	11.00	2.00	RIMS(1,4,6)	-90.	.00	.00	-80.	.00	.00	-70.	.00	.00
III -6	12.25							-67.	10.00	6.00	RIMS(1,4,5)							-67.	.00	1.36
IV -1	16.38							-55.	10.00	10.00	*NOISE							-55.	.02	6.68
IV -2	9.12				-86.	10.00	7.00	-76.	18.00	15.00	AS(4)				-86.	.03	4.97	-76.	.43	9.37
IV -3	25.40	-95.	13.00	13.00	-85.	15.00	15.00	-75.	15.00	15.00	TIM3(1,4)	-95.	.00	.12	-85.	.00	.88	-75.	.07	3.99
IV -4	7.36	-95.	12.00	4.00	-85.	23.00	14.00	-75.	29.00	24.00	*TIM3(1,3)	-95.	.00	.14	-85.	.00	1.03	-75.	.05	4.35
IV -5	3.20							-75.	10.00	1.00	*AS(4)							-75.	.21	7.77
IV -6	12.09							-75.	10.00	10.00	*NOISE							-75.	.31	9.51
V -1	16.32	-91.	10.00	1.00	-81.	20.00	1.00	-71.	23.00	1.00	RIMS(3,4,6)	-91.	.00	.07	-81.	.00	.32	-71.	.00	1.30
V -2	4.84							-70.	10.00	7.00	*NOISE							-70.	.00	1.70
V -3	24.14	-95.	12.00	2.00	-85.	14.00	3.00	-75.	27.00	6.00	*SE(6)	-95.	.00	.01	-85.	.00	.14	-75.	.00	1.03
V -4	8.16	-95.	11.00	5.00	-85.	16.00	10.00	-75.	20.00	17.00	$AS(5)	-95.	.19	7.23	-85.	.67	14.49	-75.	.84	22.29
V -5	5.30							-70.	10.00	.00	*AS(2)							-70.	.00	.11
V -6	12.07							-77.	10.00	3.00	$AS(4)							-77.	.28	9.19
VI -1	16.08				-85.	10.00	2.00	-75.	16.00	6.00	*$SE(2)				-85.	.47	10.51	-75.	1.00	19.97
VI -2	4.02							-77.	10.00	3.00	$AS(5)							-77.	.53	10.62
VI -3	9.12	-95.	16.00	2.00	-85.	23.00	3.00	-75.	14.00	9.00	AS(4)	-95.	.00	.27	-85.	.00	.96	-75.	.02	2.91
VI -4	8.18	-95.	21.00	6.00	-85.	22.00	15.00	-75.	22.00	21.00	AS(3)	-95.	.98	17.09	-85.	1.00	24.13	-75.	1.00	28.50
VI -5	5.26	-95.	11.00	2.00	-85.	11.00	2.00	-60.	11.00	2.00	AS(2)	-95.	.00	.09	-85.	.00	.25	-60.	.02	2.66
VI -6	12.07	-95.	18.00	6.00	-85.	22.00	8.00	-75.	22.00	14.00	AS(4)	-95.	.01	4.00	-85.	.39	9.38	-75.	.86	15.56
VII -1	16.32	-90.	10.00	.00	-80.	17.00	2.00	-70.	21.00	6.00	*SE(2)	-90.	.00	.01	-80.	.00	.05	-70.	.00	.36
VII -2	8.16							-65.	10.00	2.00	AS(4)							-65.	.00	2.58
VII -3	24.46	-95.	10.00	7.00	-85.	13.00	10.00	-75.	13.00	13.00	*NOISE	-95.	.02	4.95	-85.	.64	11.75	-75.	.88	18.87
VII -4	9.12	-95.	12.00	5.00	-85.	18.00	17.00	-75.	18.00	18.00	SR(5)	-95.	.00	.14	-85.	.00	.69	-75.	.00	2.34
VII -5	12.25	-95.	14.00	3.00	-85.	12.00	11.00	-75.	12.00	12.00	AS(6)	-95.	.00	.01	-85.	.00	.04	-75.	.00	.13
VII -6	12.00	NO MEASUREMENTS DUE TO EXTERNAL INTERFERENCE																		

$ INDICATES THAT THE PREDICTED MAJOR INTERACTION WAS BELOW THE AMBIENT NOISE LEVEL
* INDICATES THAT THE PREDICTED MAJOR INTERACTION WAS ALSO A SIGNIFICANT MEASURED INTERACTION

TABLE B-1

(Page 2 of 4)

TEST NO.	FREQ. MHZ	MEASURED VALUES PD.	S+N/N	SINAD	PD.	S+N/N	SINAD	PD.	S+N/N	SINAD	MAJOR PREDICTED INTERACTION	PREDICTED VALUES PD.	SPS	SINAD	PD.	SPS	SINAD	PD.	SPS	SINAD
VIII -1	16.32							-55.	10.00	3.00	*SR(4)							-55.	.01	5.12
VIII -2	5.82				-80.	10.00	.00	-70.	15.00	.00	*AS(5)				-80.	.00	.00	-70.	.00	.00
VIII -3	23.91	-89.	10.00	1.00	-79.	19.00	1.00	-69.	29.00	1.00	*AS(6)	-89.	.00	.11	-79.	.00	.39	-69.	.01	1.26
VIII -4	16.08				-85.	10.00	1.00	-75.	20.00	2.00	*SR(1)				-85.	.00	1.48	-75.	.02	4.87
VIII -5	5.88				-85.	10.00	.00	-75.	15.00	.00	*AS(2)				-85.	.00	.00	-75.	.00	.00
VIII -6	23.71	-95.	10.00	1.00	-85.	18.00	1.00	-75.	28.00	1.00	*AS(3)	-95.	.00	.12	-85.	.00	.40	-75.	.01	1.25
IX -1	16.39							-70.	10.00	10.00	*NOISE							-70.	.46	10.39
IX -2	5.88							-58.	10.00	9.00	AS(5)							-58.	.12	6.13
IX -3	24.46	-90.	10.00	1.00	-80.	19.00	1.00	-70.	27.00	1.00	*AS(6)	-90.	.00	1.03	-80.	.03	2.64	-70.	.18	5.81
IX -4	17.46	-95.	18.00	18.00	-85.	19.00	19.00	-75.	19.00	19.00	AS(1)	-95.	.91	14.53	-85.	1.00	21.19	-75.	1.00	26.54
IX -5	5.43	-95.	11.00	1.00	-85.	11.00	2.00	-75.	11.00	2.00	*AS(2)	-95.	.00	.01	-85.	.00	.03	-75.	.00	.12
IX -6	24.13	-95.	22.00	1.00	-85.	22.00	1.00	-75.	22.00	3.00	*AS(3)	-95.	.01	1.19	-85.	.04	2.91	-75.	.21	6.31
X -1	16.08							-62.	10.00	10.00	*NOISE							-62.	.00	4.81
X -2	5.30							-57.	10.00	10.00	*NOISE							-57.	.21	7.66
X -3	25.39	-95.	10.00	7.00	-85.	19.00	16.00	-75.	28.00	26.00	*NOISE	-95.	.03	5.78	-85.	.65	12.10	-75.	.93	18.86
X -4	5.88	-95.	21.00	16.00	-85.	21.00	20.00	-75.	21.00	21.00	AS(2)	-95.	.96	16.63	-85.	1.00	23.26	-75.	1.00	26.99
X -5	17.46							-55.	10.00	2.00	$AS(1)							-55.	.12	7.44
X -6	23.91	-95.	14.00	5.00	-85.	23.00	11.00	-75.	31.00	20.00	*AS(3)	-95.	.27	8.28	-85.	.84	15.05	-75.	.98	19.95
XI -1	16.08	-95.	10.00	2.00	-85.	18.00	2.00	-75.	26.00	2.00	$AS(4)	-95.	.49	10.39	-85.	1.00	20.04	-75.	1.00	29.51
XI -2	4.52	-95.	11.00	2.00	-85.	13.00	2.00	-75.	14.00	2.00	*AS(5)	-95	.01	2.57	-85.	.10	4.05	-75.	.23	6.04
XI -3	25.56	-95.	10.00	2.00	-85.	18.00	3.00	-75.	23.00	3.00	*AS(6)	-95.	.00	2.91	-85.	.29	8.13	-75.	.77	14.45
XI -4	3.19	-95.	15.00	2.00	-85.	22.00	3.00	-75.	23.00	10.00	$AS(5)	-95.	.90	13.01	-85.	1.00	22.89	-75.	1.00	29.91
XI -5	4.96							-69.	10.00	2.00	*SR(2)							-69.	.00	.00
XI -6	24.86	-95.	10.00	1.00	-85.	17.00	2.00	-75.	21.00	2.00	*AS(3)	-95.	.02	5.14	-85.	.59	11.15	-75.	.89	17.04
XII -1	16.32	-95.	10.00	2.00	-85.	20.00	2.00	-75.	25.00	5.00	*$AS(3)	-95.	.30	9.58	-85.	.99	17.78	-75.	1.00	25.39
XII -2	3.18	NO PREDICTION DUE TO ABSENCE OF RECEIVER RECORD FOR THIS BAND																		
XII -3	17.46				-82.	10.00	3.00	-72.	19.00	5.00	*AS(1)				-82.	.02	3.83	-72.	.34	8.27
XII -4	4.89				-78.	10.00	6.00	-68.	19.00	15.00	*NOISE				-78.	.21	7.51	-68.	.69	14.70
XII -5	5.86							-65.	10.00	8.00	AS(4)							-65.	.00	.26
XII -6	24.46	-95.	10.00	4.00	-85.	18.00	12.00	-75.	22.00	20.00	*$AS(4)	-95.	.17	8.39	-85.	.94	16.07	-75.	1.00	21.20
XIII -1	16.08	-88.	10.00	3.00	-78.	20.00	11.00	-68.	25.00	19.00	$AS(3)	-88.	.45	10.32	-78.	1.00	19.44	-68.	1.00	28.15
XIII -2	8.06	-95.	10.00	2.00	-85.	16.00	2.00	-75.	14.00	3.00	*SE(5)	-95.	.00	.00	-85.	.00	.00	-75.	.00	.00
XIII -3	17.46				-85.	10.00	7.00	-75.	18.00	15.00	AS(1)				-85.	.01	3.21	-75.	.29	7.63
XIII -4	12.09	-95.	12.00	2.00	-85.	18.00	2.00	-75.	22.00	5.00	*SE(5)	-95.	.00	.00	-85.	.00	.01	-75.	.00	.08
XIII -5	4.03	-95.	11.00	2.00	-85.	12.00	2.00	-75.	12.00	3.00	RIM3(2,4)	-95.	.00	.00	-85.	.00	.00	-75.	.00	.00
XIII -6	24.21	-95.	12.00	2.00	-85.	19.00	3.00	-75.	22.00	10.00	*$AS(4)	-95.	.28	8.65	-85.	.90	15.82	-75.	.99	20.58
XIV -1	16.39	-95.	10.00	10.00	-85.	19.00	17.00	-75.	20.00	26.00	*NOISE	-95.	.28	9.39	-85.	.99	17.47	-75.	1.00	24.94
XIV -2	17.48	NO PREDICTION DUE TO ABSENCE OF RECEIVER RECORD FOR THIS BAND																		
XIV -3	29.90	-95.	10.00	6.00	-85.	28.00	24.00	-75.	22.00	20.00	*NOISE	-95.	.10	7.32	-85.	.83	14.47	-75.	.98	22.12
XIV -4	8.06	-95.	14.00	10.00	-85.	21.00	18.00	-75.	23.00	23.00	*NOISE	-95.	.66	10.80	-85.	.89	19.69	-75.	.96	27.24
XIV -5	4.61	-95.	10.00	1.00	-85.	11.00	4.00	-75.	11.00	6.00	*AS(4)	-95.	.00	.96	-85.	.02	3.34	-75.	.20	7.02
XIV -6	23.74	-95.	15.00	15.00	-85.	21.00	21.00	-75.	21.00	21.00	*NOISE	-95.	.54	10.45	-85.	.95	17.56	-75.	.99	21.32

$ INDICATES THAT THE PREDICTED MAJOR INTERACTION WAS BELOW THE AMBIENT NOISE LEVEL
* INDICATES THAT THE PREDICTED MAJOR INTERACTION WAS ALSO A SIGNIFICANT MEASURED INTERACTION

TABLE B-1

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TEST NO.	FREQ. MHZ	MEASURED VALUES PD.	S+N/N	SINAD	PD.	S+N/N	SINAD	PD.	S+N/N	SINAD	MAJOR PREDICTED INTERACTION	PREDICTED VALUES PD.	SPS	SINAD	PD.	SPS	SINAD	PD.	SPS	SINAD
XV -1	16.08	-95.	10.00	2.08	-85.	16.00	7.00	-75.	19.00	16.00	$AS(2)	-95.	.47	10.43	-85.	1.00	20.01	-75.	1.00	29.51
XV -2	3.18	NO PREDICTION DUE TO ABSENCE OF RECEIVER RECORD FOR THIS BAND																		
XV -3	29.90	-95.	10.00	9.00	-85.	18.00	18.00	-75.	21.00	21.00	*NOISE	-95.	.16	8.40	-85.	.93	16.21	-75.	1.00	24.52
XV -4	5.85	-95.	20.00	2.00	-85.	22.00	2.00	-75.	22.00	4.00	$AS(5)	-95.	.99	17.41	-85.	.99	27.06	-75.	1.08	29.92
XV -5	11.78				-80.	10.00	2.00	-70.	15.00	4.00	SE(4)				-80.	.00	.01	-70.	.00	.09
XV -6	25.70	-95.	15.00	12.00	-85.	20.00	19.00	-75.	21.00	21.00	*NOISE	-95.	.61	11.05	-85.	.96	18.06	-75.	1.00	21.40
XVI -1	16.08	-90.	10.00	2.00	-80.	18.00	5.00	-70.	21.00	13.00	SE(5)	-90.	.02	4.86	-80.	.72	12.87	-70.	.99	22.57
XVI -2	3.20	NO PREDICTION DUE TO ABSENCE OF RECEIVER RECORD FOR THIS BAND																		
XVI -3	4.61	-95.	13.00	3.00	-85.	14.00	8.00	-75.	12.00	12.00	*RIM3(2,4,5)	-95.	.00	.00	-85.	.00	.00	-75.	.00	.00
XVI -4	5.43	-95.	10.00	1.00	-85.	18.00	1.00	-75.	18.00	1.00	*$AS(3)	-95.	.02	5.63	-85.	.69	12.58	-75.	.80	20.69
XVI -5	4.02				-85.	10.00	2.00	-75.	11.00	2.00	*RIM3(2,3,4)				-85.	.00	.00	-75.	.00	.00
XVI -6	25.70	-95.	10.00	10.00	-85.	15.00	15.00	-75.	17.00	17.00	*NOISE	-95.	.18	5.49	-85.	.95	16.34	-75.	1.00	21.39
XVII -1	16.08	-95.	10.00	4.00	-85.	17.00	10.00	-75.	22.00	20.00	$AS(3)	-95.	.49	10.47	-85.	1.00	20.08	-75.	1.09	29.44
XVII -2	12.09	-88.	10.00	2.00	-78.	17.00	8.00	-68.	17.00	14.00	$AS(5)	-88.	.39	10.06	-78.	1.00	18.56	-68.	1.00	20.00
XVII -3	5.30	-95.	10.00	10.00	-85.	14.00	14.00	-75.	12.00	12.00	AS(4)	-95.	.00	1.21	-85.	.03	3.48	-75.	.23	7.31
XVII -4	7.36	-88.	10.00	3.00	-78.	18.00	8.00	-68.	20.00	14.00	*AS(5)	-88.	.26	9.30	-78.	.99	17.01	-68.	1.00	24.19
XVII -5	8.16				-85.	10.00	2.00	-75.	11.00	2.00	*AS(4)				-85.	.00	.04	-75.	.00	.09
XVII -6	24.94	-95.	10.00	8.00	-85.	16.00	16.00	-75.	19.00	19.00	*NOISE	-95.	.29	9.30	-85.	.98	17.71	-75.	1.00	21.75
XVIII-1	16.39	-89.	10.00	8.00	-79.	16.00	14.00	-69.	20.00	19.00	RIM5(2,4,5)	-89.	.00	.00	-79.	.00	.01	-69.	.00	.05
XVIII-2	5.85				-80.	10.00	10.00	-70.	15.00	15.00	AS(5)				-80.	.08	5.52	-70.	.48	9.66
XVIII-3	27.60	-95.	10.00	1.00	-85.	20.00	3.00	-75.	27.00	9.00	$AS(6)	-95.	.09	7.30	-85.	.87	14.66	-75.	.99	21.89
XVIII-4	17.48	-95.	14.00	4.00	-85.	23.00	6.00	-75.	27.00	13.00	AS(1)	-95.	.78	12.29	-85.	.99	20.08	-75.	1.00	26.28
XVIII-5	5.30	-87.	10.00	1.00	-77.	11.00	1.00	-67.	11.00	2.00	*AS(2)	-87.	.00	.05	-77.	.00	.15	-67.	.00	.40
XVIII-6	24.94	-95.	10.00	7.00	-85.	19.00	16.00	-75.	26.00	24.00	$AS(4)	-95.	.11	7.77	-85.	.88	15.08	-75.	.99	20.61
XIX -1	16.32	-92.	10.00	8.00	-82.	17.00	16.00	-72.	29.00	19.00	*NOISE	-92.	.37	9.92	-82.	1.00	18.47	-72.	1.00	26.74
XIX -2	7.36				-76.	10.00	2.00	-66.	19.00	6.00	$AS(5)				-76.	.64	11.23	-66.	1.00	19.42
XIX -3	25.56				-85.	10.00	1.00	-75.	19.00	[illegible].00	*AS(6)				-85.	.07	6.56	-75.	.73	13.06
XIX -4	17.50	-95.	15.00	2.00	-85.	24.00	6.00	-75.	28.00	14.00	AS(1)	-95.	.87	12.82	-85.	1.00	20.70	-75.	1.00	27.14
XIX -5	4.56				-85.	10.00	1.00	-75.	12.00	1.00	SR(3)(NF)				-85.	.00	3.34	-75.	.29	8.28
XIX -6	24.92	-95.	10.00	1.00	-85.	18.00	1.00	-75.	26.00	1.00	*AS(3)	-95.	.02	5.14	-85.	.52	10.51	-75.	.87	16.74
XX -1	23.71	-95.	11.00	3.00	-85.	14.00	9.00	-75.	13.00	13.00	*SR(6)	-95.	.23	8.62	-85.	.98	17.67	-75.	1.00	27.16
XX -2	11.63				-85.	10.00	4.00	-75.	15.00	12.00	*AS(5)				-85.	.00	.43	-75.	.00	.83
XX -3	4.84	-95.	22.00	22.00	-85.	18.00	18.00	-75.	12.00	12.00	AS(4)	-95.	.10	4.79	-85.	.41	9.62	-75.	.77	15.49
XX -4	8.17	-95.	11.00	11.00	-85.	19.00	19.00	-75.	22.00	22.00	*NOISE	-95.	.65	11.35	-85.	1.00	21.05	-75.	1.00	29.54
XX -5	12.09				-85.	10.00	2.00	-75.	11.00	2.00	AS(2)				-85.	.00	.30	-75.	.00	.76
XX -6	24.21	-93.	10.00	1.00	-83.	17.00	1.00	-73.	2[illegible].00	3.00	*AS(1)	-93.	.00	2.95	-83.	.27	7.63	-73.	.67	13.20
XXI -1	23.74	-93.	10.00	1.00	-83.	18.00	2.00	-73.	1[illegible].00	10.00	*SR(6)	-93.	.00	.03	-83.	.00	.24	-73.	.00	1.13
XXI -2	17.48	NO PREDICTION DUE TO ABSENCE OF RECEIVER RECORD FOR THIS BAND																		
XXI -3	4.96	-95.	10.00	1.00	-85.	18.00	3.00	-75.	13.00	8.00	*RIM2(4,5)	-95.	.00	.00	-85.	.00	.01	-75.	.00	.05
XXI -4	8.16	-95.	12.00	1.00	-85.	19.00	6.00	-75.	20.00	13.00	*RIM2(3,5)	-95.	.00	1.40	-85.	.14	5.37	-75.	.61	12.87
XXI -5	3.20	-95.	10.00	1.00	-85.	12.00	1.00	-75.	12.00	2.00	AS(3)	-95.	.00	.83	-85.	.01	2.12	-75.	.05	3.93
XXI -6	24.87	-92.	10.00	6.00	-82.	18.00	15.00	-75.	25.00	25.00	AS(1)	-92.	.07	6.91	-82.	.81	14.05	-75.	.95	18.53

$ INDICATES THAT THE PREDICTED MAJOR INTERACTION WAS BELOW THE AMBIENT NOISE LEVEL
* INDICATES THAT THE PREDICTED MAJOR INTERACTION WAS ALSO A SIGNIFICANT MEASURED INTERACTION

TABLE B-1

(Page 4 of 4)

TEST NO.	FREQ. MHZ	MEASURED VALUES PO.	S+N/N	SINAD	PO.	S+N/N	SINAD	PO.	S+N/N	SINAD	MAJOR PREDICTED INTERACTION	PREDICTED VALUES PO.	SPS	SINAD	PO.	SPS	SINAD	PO.	SPS	SINAD
XXII -1	23.74	-95.	10.00	1.00	-85.	14.00	3.00	-75.	15.00	8.00	*RIM2(2,4)	-95.	.00	.00	-85.	.00	.01	-75.	.00	.06
XXII -2	16.38	NO PREDICTION DUE TO ABSENCE OF RECEIVER RECORD FOR THIS BAND																		
XXII -3	17.46				-82.	10.00	2.00	-72.	18.00	2.00	*AS(2)				-82.	.00	1.33	-72.	.07	3.83
XXII -4	7.36				-83.	10.00	8.00	-73.	20.00	17.00	SR(5)(LF)				-83.	.00	.24	-73.	.00	1.56
XXII -5	9.12							-70.	10.00	2.00	*AS(4)							-70.	.00	1.34
XXII -6	25.39	-95.	13.00	13.00	-85.	22.00	22.00	-75.	30.00	30.00	AS(1)	-95.	.42	9.37	-85.	.87	16.04	-75.	.98	20.56
XXIII-1	24.13	-95.	10.00	1.00	-85.	15.00	1.00	-75.	15.00	1.00	SR(6)(UF)	-95.	.00	.02	-85.	.00	.12	-75.	.00	.56
XXIII-2	4.02							-60.	10.00	9.00	AS(3)							-60.	.00	2.54
XXIII-3	3.34	-95.	23.00	22.00	-85.	18.00	18.00	-75.	13.00	13.00	AS(2)	-95.	.00	.01	-85.	.00	.05	-75.	.00	.18
XXIII-4	4.56							-55.	10.00	10.00	*NOISE							-55.	.39	9.92
XXIII-5	9.12							-70.	10.00	1.00	*SE(4)							-70.	.00	.19
XXIII-6	25.56	-95.	13.00	12.00	-85.	22.00	21.00	-75.	31.00	29.00	AS(1)	-95.	.28	8.13	-85.	.81	14.66	-75.	.97	19.58
XXIV -1	24.13	-95.	11.00	1.00	-85.	15.00	1.00	-75.	15.00	2.00	*SE(2)	-95.	.02	4.69	-95.	.66	12.20	-75.	.99	21.88
XXIV -2	4.02							-60.	10.00	10.00	AS(4)							-60.	.16	7.18
XXIV -3	27.77	-95.	10.00	6.00	-85.	17.00	13.00	-75.	24.00	22.00	AS(1)	-95.	.02	4.99	-85.	.54	10.66	-75.	.86	17.18
XXIV -4	4.64							-68.	10.00	7.00	*NOISE							-68.	.26	8.75
XXIV -5	5.85							-75.	10.00	4.00	*RIM5(2,4)							-75.	.00	.00
XXIV -6	25.45	-95.	11.00	10.00	-85.	20.00	19.00	-75.	27.00	27.00	AS(1)	-95.	.06	6.46	-85.	.74	12.96	-75.	.94	18.78
XXV -1	24.21	-95.	11.00	2.00	-85.	13.00	5.00	-75.	13.00	11.00	RIM5(2,5,6)	-95.	.00	.00	-85.	.00	.01	-75.	.00	.05
XXV -2	4.02	NO PREDICTION DUE TO ABSENCE OF RECEIVER RECORD FOR THIS BAND																		
XXV -3	27.75	-92.	10.00	4.00	-82.	18.00	11.00	-72.	22.00	18.00	*RIM5(1,6)	-92.	.00	.00	-82.	.00	.02	-72.	.00	.08
XXV -4	5.20	-95.	15.00	2.00	-85.	22.00	2.00	-75.	23.00	3.00	TIM3(2,5)	-95.	.00	.00	-85.	.00	.00	-75.	.00	.00
XXV -5	4.61	-95.	12.00	2.00	-85.	12.00	5.00	-75.	12.00	7.00	*AS(4)	-95.	.00	.00	-85.	.00	.00	-75.	.00	.01
XXV -6	25.39	-95.	11.00	2.00	-85.	20.00	6.00	-75.	24.00	13.00	*RIM3(1,2,4)	-95.	.00	.64	-85.	.03	2.95	-75.	.34	8.69

$ INDICATES THAT THE PREDICTED MAJOR INTERACTION WAS BELOW THE AMBIENT NOISE LEVEL

* INDICATES THAT THE PREDICTED MAJOR INTERACTION WAS ALSO A SIGNIFICANT MEASURED INTERACTION

For example if the major predicted interaction appears as "*AS(5)," then an adjacent signal interfering emission from the transmitter at terminal 5 was the predicted major source of interference. The "*" denotes that this adjacent signal interference from transmitter 5 was identified as an interferer by measurement.

Similarly if no symbol prefixes the major predicted interaction in TABLE B-1 such as "AS(5)," then this interference was not identified during the interferer identification measurements.

If the major predicted interaction appears as "$AS(5)," then this adjacent signal interaction was predicted to be below the environment noise level and some other interaction was found to be above the noise level.

"*$AS(5)" means that the predicted mean adjacent signal interference was below the ambient noise, but it was both measured and predicted as a major interaction.

In the predicted values columns, SPS is the predicted system performance score (the probability of exceeding an output of 10 dB). $\overline{S}p$ is the mean SINAD of the predicted distribution in dB.

General Comments

TABLE B-2 summarizes the computed mean values (i.e., bias), and standard deviation, $\sigma(\Delta)$, of the quantity $S_m - \overline{S}_p$, where S_m is the measured SINAD output and $\overline{S}_p$ is the predicted SINAD mean value (see Equations 1 and 2). The condition errors indicate the number (and percent) of the cases which resulted in zero condition error, one-condition error, etc., as defined in TABLE 3.

TABLE B-2

SUMMARY OF dB VARIATIONS AND CONDITION ERRORS
(Page 1 of 2)

Interactions	$S_m - \bar{S}_p$, dB Mean	σ	Number and Percent of Measured Cases in Error by the Following # of Conditions: 0 No.	0 %	1 No.	1 %	2 No.	2 %	3 No.	3 %	4 No.	4 %	Total Cases
ALL	-.54	7.60	160	46.4	84	24.3	55	15.9	27	7.8	19	5.5	345
ADJACENT SIGNAL	-1.09	7.74	61	45.2	[illegible]	21.4	27	20.0	9	6.7	9	6.7	135
NOISE	-.23	3.37	20	41.7	24	50.0	4	8.3	0	0.0	0	0.0	48
SR (ALL CASES)	1.60	8.10	9	47.4	4	21.1	3	15.8	3	15.8	0	0.0	19
SR PRED. & NOTED	1.21	6.64	5	41.6	3	25.0	2	16.7	2	16.7	0	0.0	12
SR PR[illegible] BUT NOT NOTED	2.27	6.78	4	57.1	1	14.3	1	14.3	1	14.3	0	0.0	7
SE (ALL CASES)	-1.63	6.74	14	60.9	4	17.4	2	8.7	2	8.7	1	4.3	23
SE PRED. & NOTED	-1.28	7.05	11	61.1	3	16.7	1	5.6	2	11.1	1	5.6	[illegible]8
SE PRED. BUT NOT NOTED	-2.88	5.28	3	60.0	1	20.0	1	20.0	0	0.0	0	0.0	5
IM (RIM & TIM)	-.18	8.56	56	46.7	23	19.2	19	15.8	13	10.8	9	7.5	120
RIM (ALL CASES)	-1.08	8.39	49	45.8	23	21.5	18	16.8	9	8.4	8	7.5	1[illegible]
2-SIGNAL RIM (ALL)	-2.23	8.76	26	45.6	10	17.5	9	15.8	7	12.3	5	8.8	57
PREDICTED AND NOTED	4.70	5.06	8	61.5	1	7.7	3	23.1	1	7.7	0	0.0	13
PREDICTED BUT NOT NOTED	6.98	5.73	4	[illegible].1	0	0.0	2	28.6	0	0.0	1	14.3	7
NOTED BUT NOT PREDICTED	-6.[illegible]	7.[illegible]	14	37.8	9	24.3	4	10.8	6	16.2	4	[illegible].8	37
2ND ORDER, 2-SIGNAL	5.0[illegible]	[illegible].30	7	53.8	1	7.7	4	30.8	0	0.0	1	[illegible].7	13
PREDICTED AND NOTED	2.69	3.01	6	66.7	1	11.1	2	22.2	0	0.0	0	0.0	9
PREDICTED [illegible] NOT NOTED	10.46	5.39	1	25.0	0	0.0	2	50.0	0	0.0	1	25.0	4
3RD ORDER, SIG[illegible]	2.33	0.47	3	100.0	0	0.0	0	0.0	0	0.0	0	0.0	3
PREDICTED AND [illegible]	-	-	-	-	-	-	-	-	-	-	-	-	0
PREDICTED [illegible] NOT NOTED	2.33	0.47		[illegible]00.0	0	0.0	0	0.0	0	0.0	0	0.0	3
5TH ORDER, 2-	9.23	5.7[illegible]			0	0.0	1	25.0	1	25.0	0	0.0	4
PREDICTED AN[illegible]	9.23	5.7[illegible]			0	0.0	1	25.0	1	25.0	0	0.0	4
PREDICTED BUT N[illegible] NOTED	-	-			-	-	-	-	-	-	-	-	0

TABLE B-2

(Page 2 of 2)

Interactions	$S_m - \overline{S}_p$, dB Mean	σ	Number and Percent of Measured Cases in Error by the Following # of Conditions: 0 No.	0 %	1 No.	1 %	2 No.	2 %	3 No.	3 %	4 No.	4 %	Total Cases
3-SIGNAL RIM (ALL)	-.23	7.73	23	46.0	13	26.0	9	18.0	2	4.0	3	6.0	50
PREDICTED AND NOTED	4.46	3.45	4	50.0	1	12.5	3	37.5	0	0.0	0	0.0	8
PREDICTED BUT NOT NOTED	5.16	5.07	9	50.0	4	22.2	3	16.7	1	5.6	1	5.6	18
NOTED BUT NOT PREDICTED	-4.89	7.13	10	41.7	8	33.3	3	12.5	1	4.2	2	8.3	24
3RD ORDER, 3-SIGNAL	4.46	3.45	4	50.0	1	12.5	3	37.5	0	0.0	0	0.0	8
PREDICTED AND NOTED	4.46	3.45	4	50.0	1	12.5	3	37.5	0	0.0	0	0.0	8
PREDICTED BUT NOT NOTED	-	-	-	-	-	-	-	-	-	-	-	-	0
5TH ORDER, 3-SIGNAL	5.16	5.07	9	50.0	4	22.2	3	16.7	1	5.6	1	5.6	18
PREDICTED AND NOTED	-	-	-	-	-	-	-	-	-	-	-	-	0
PREDICTED BUT NOT NOTED	5.16	5.07	9	50.0	4	22.2	3	16.7	1	5.6	1	5.6	18
TIM (ALL CASES)	7.27	5.96	7	53.8	0	0.0	1	7.7	4	30.8	1	7.7	13
PREDICTED AND NOTED	7.07	5.49	4	57.1	0	0.0	1	14.3	1	14.3	1	14.3	7
PREDICTED BUT NOT NOTED	7.50	5.26	3	50.0	0	0.0	0	0.0	3	50.0	0	0.0	6

The data in this table provide three different, though related, measures of comparison between measured and predicted values. Examining all interactions, we note a mean difference value of -0.54 dB. This indicates that for all 345 interactions, on the average, COSAM predicted the output mean SINAD values to be greater than the associated measured values, representing less interference by this amount. Considering the fact that all measured values were reported to the nearest dB, the likelihood of some measurement error, the fact that the average (rather than the precise) value of transmitter power was used, and the other numerous uncertainties involved, it is concluded that -0.54 dB is a negligibly small bias. This value compares favorably with the 1.55 dB mean deviation resulting from UHF validation and the -1.72 dB mean difference from the VHF validation (see TABLES B-3 and B-4 respectively).

The second measure, $\sigma(\Delta)$, indicates the spread of the deviations between the measured values and the predicted means.

Figure B-1, is a cumulative plot of the distribution. The value of $\sigma(\Delta)$, for all interactions, is 7.6 dB, representing about 72% of the cases. A value of 10 dB represents approximately 82% of the cases. This is compared with the values derived from the UHF and VHF studies (References 2 and 4) in Figure B-1. The values of $\sigma(\Delta)$ provide approximate measures of deviation from the measured values which can be compared with each other.

The third measure, involving condition errors, indicates that 71% of all cases resulted in no more than 1-condition error, while 8[illegible]% of the cases resulted in no more than a 2-condition error. These percentages are slightly less than those experienced in either the UHF or VHF validation efforts.

TABLE B-3

SUMMARY OF MAJOR UHF VALIDATION RESULTS
(FROM REFERENCE 2)

Interaction Types	B (dB)	$\sigma(\Delta)$ (dB)	P_{2c}	Number of Cases	% Cases
All Interactions	1.55	5.34	0.92	436	100
Adjacent Signal	2.01	3.93	0.98	111	25.5
Noise	0.30	1.72	1.00	136	31.2
Spurious Responses	1.51	7.10	0.87	63	14.4
(a) predicted and noted	2.25	6.21	0.89	54	12.4
(b) noted but not predicted	-9.44	3.96	0.83	6	1.4
(c) predicted but not noted	10.12	3.05	0.33	3	0.7
Spurious Emissions	6.39	8.11	0.78	9	2.1
Receiver Intermodulation (IM)	2.22	7.18	0.83	117	26.8
(a) 2-signal IM; 3rd,5th,7th orders	3.48	5.83	0.89	65	14.9
(b) 3-signal IM; 3rd,5th orders	1.86	7.34	0.79	48	11.0
(c) 3-signal IM noted but not predicted	-13.98	4.36	0.25	4	0.9

TABLE B-3

SUMMARY OF MAJOR VHF VALIDATION RESULTS
(FROM REFERENCE 4)

Interaction Types	B (dB)	$\sigma(\Delta)$ (dB)	P_{2c}	Number of Cases	% Cases
All Interactions	-1.72	5.58	0.92	561	100.0
Adjacent Signal	-1.64	5.03	0.94	224	39.9
Noise	-2.86	4.69	0.92	76	13.5
Spurious Responses	-0.93	6.77	0.90	61	10.9
Predicted & Noted	-1.21	6.47	0.92	60	10.7
Predicted But Not Noted	15.73	-	0.00	1	0.2
Spurious Emissions	-2.32	4.75	0.93	44	7.8
Receiver Intermodulation	-1.27	6.32	0.89	151	26.9
2-Signal, 2nd, 3rd, 5th Orders	1.11	3.47	1.00	62	11.1
3-Signal, 3rd, 5th Orders	-0.39	6.32	0.92	60	10.7
2-Signal Noted But Not Predicted	-9.11	6.65	0.65	20	3.6
3-Signal Noted But Not Predicted	-6.12	4.20	0.67	9	1.6
Transmitter Intermodulation	-6.05	2.93	0.80	5	0.9

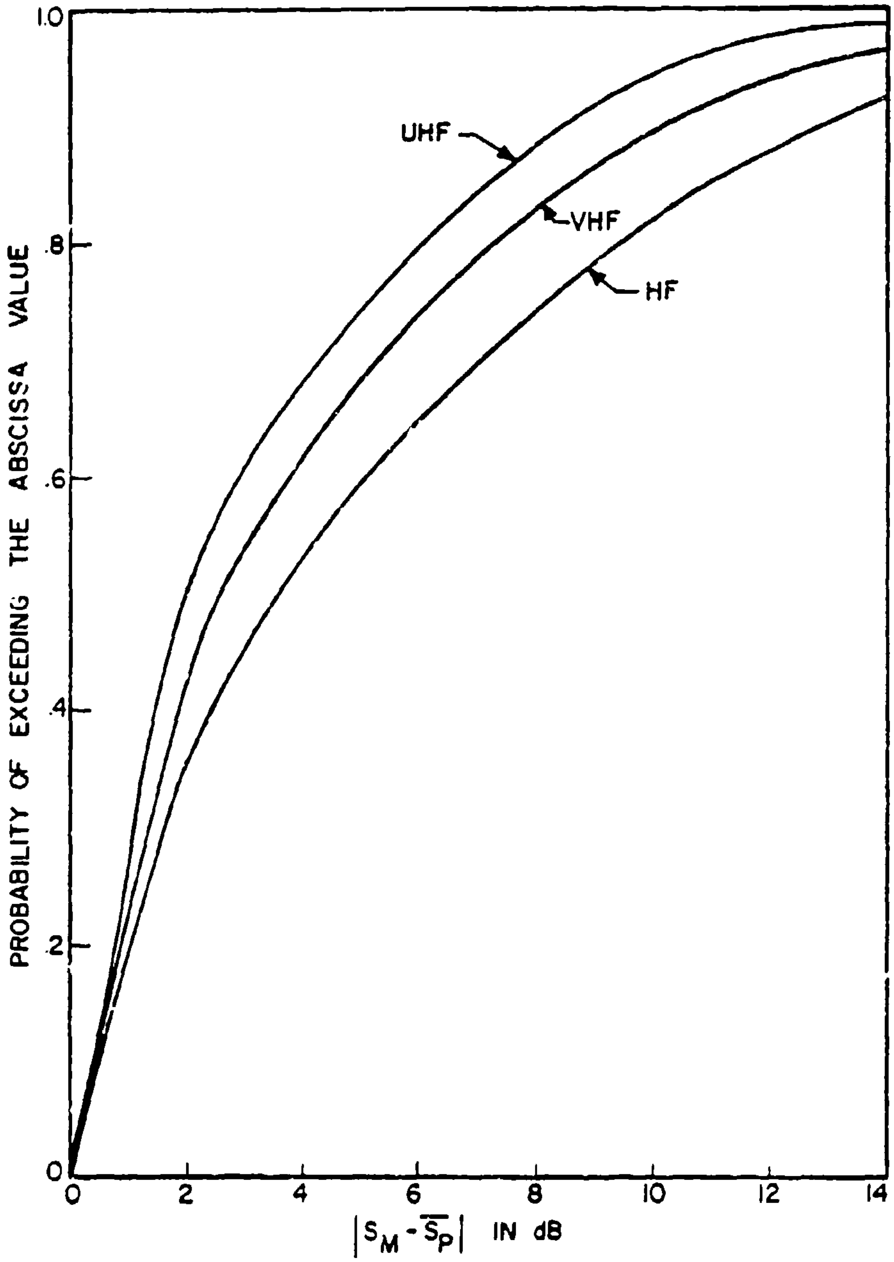

Figure B-1. Cumulative probability distribution of $|S_M - \overline{S}_p|$.

The measures of condition error provide somewhat cruder, though meaningful, results than those provided by the values of B and $\sigma(\Delta)$. As seen in TABLE B-2, there were 27 cases involving 3-condition errors and 19 cases involving 4-condition errors (a total of 13%). These and other apparently large deviations are discussed in a following section.

Evaluation of $\sigma(\overline{S}_p)$

Figure B-2 represents a measure of the relationships between S_M, $\overline{S}_p$, and $\sigma(\overline{S}_p)$ (the standard deviation of the predicted SINAD output distribution around $\overline{S}_p$). The probability value for 1σ was .36 which is much less than what would be achieved by a normal distribution. The values for 2σ, 3σ, etc., are also much less than what would be exhibited by a normal distribution.

The individual interactions were not analyzed in detail, but it appears that the $\sigma(\overline{S}_p)$ values are less than the associated values of $|S_M - \overline{S}_p|$ in approximately 65% of the cases. In 15 to 20% of the cases the $\sigma(\overline{S}_p)$ values are relatively small compared to the associated values of $|S_M - \overline{S}_p|$.

One possible explanation for the occurrence of small $\sigma(\overline{S}_p)$ values is worth noting. COSAM initially predicts output values of $[S/(I+N)]$ with an associated σ. If severe interference is predicted, large negative values are computed. When these are converted to SINAD values, most are found to be equal to or slightly greater than zero. Hence, even if the σ of the $[S/(I+N)]$ output distribution is large, the σ of the SINAD distribution can be quite small. A similar situation arises if little or no interference is predicted.

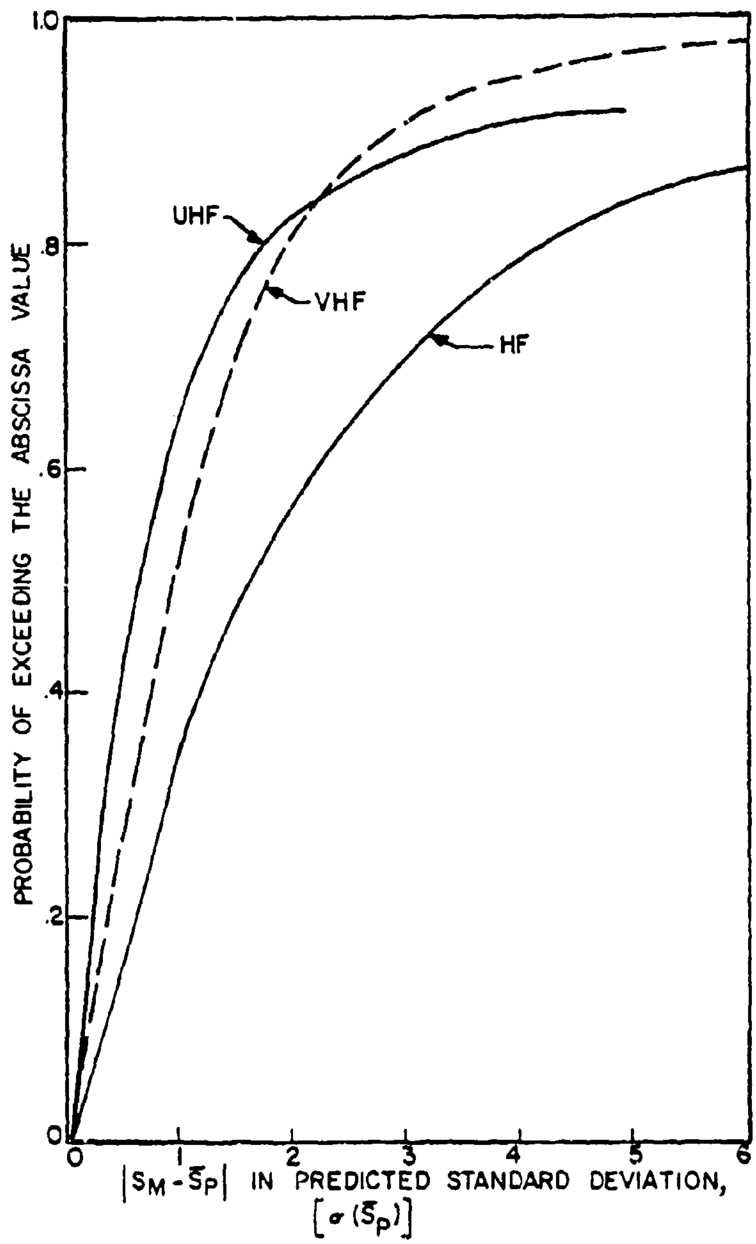

Figure B-2. Cumulative distribution of relationship between $|S_M - \bar{S}_p|$ and $\sigma(\bar{S}_p)$.

DISCUSSION OF INDIVIDUAL INTERACTIONS

This section discusses the results obtained by comparing the measured and predicted data compiled for each type of interaction.

Adjacent Signal

As noted in TABLE B-2, and TABLE 5, the values of B, $\sigma(\Delta)$, P_{1c} and P_{2c} for adjacent signal interactions were -1.09, 7.74, 0.67 and 0.87 respectively.

The values of B and $\sigma(\Delta)$ for these 135 cases suggests that the adjacent-signal model is computing a mean value which is close to the measured values, with a small optimistic bias. The standard deviation [$\sigma(\Delta)$] indicates that rather large excursions from the mean values ($\bar{S}_p$) do occur, implying that continued analyses of antenna-to-antenna coupling in the 2-30 MHz band, HF antenna coupler effects, transmitter and receiver impedances and transmitter noise characteristics need to be pursued. The P_{2c} value tends to substantiate this assertion. Predicted adjacent-signal interactions contributed 29 of the 62 gross error cases. Most of these cases can be attributed to coupling prediction errors. A few may be due to spurious emissions (and possibly spurious responses) which occurred but were not predicted. The preponderance of cases involving errors where insufficient interference levels were predicted may also be due to inadequate portrayal of cumulative transmitter noise effects. A further discussion of gross error cases will appear in a following section.

Noise

This interaction refers to those cases where no apparent interference due to a specific transmitter, or a specific combination of transmitters, was present. The values of B, $\sigma(\Delta)$, P_{1c}, P_{2c}, were: -0.23, 3.37, .92 and 1.00, respectively, for 48 cases.

These interactions predicted by COSAM as being due to noise were not identified by the measurement agency as being due to a specific transmitter.

There were no cases said to be due to noise that resulted in 3- or 4-condition errors. It should be noted that estimates of ambient noise were based on field measurements of (S+N)/N values.

Spurious Emissions

As noted in TABLE B-2 and TABLE 5, the values of B, $\sigma(\Delta)$, P_{1c}, and P_{2c} for all spurious emission cases were -1.63, 6.74, .78, and .87, respectively, for 23 samples. Of the 23 cases, only 3 resulted in 3- and 4-condition errors. Two gross-error cases represented the same emission (interaction XXIV-1), but at differing desired-signal power levels, with the SINAD error (S_M - $\overline{S}_p$) increasing with desired power levels. This emission of the T368/URT transmitter at terminal 2 was predicted, but the comparison with measured data indicated that the interfering level of this emission was predicted inaccurately. One possible explanation of this occurrence is that the BC-939-B Coupler model calculated too much loss at the spurious emission frequency, thus causing COSAM to predict a high SINAD value in relation to the measured SINAD. The third gross error case (assignment VI-1) resulted once again from a highly optimistic COSAM

SINAD prediction, although both the major predicted and measured interferers were the same terminals. This tends to reinforce the assertion that effort is needed to obtain more accurate estimates of transmitter impedances which are required for coupler models.

Spurious Responses

TABLES 5 and B-2 list the values of B, $\sigma(\Delta)$, P_{1c}, and P_{2c} for all spurious response interactions as 1.60, 8.1, 0.68, and 0.84, respectively, for 19 samples. These results show slightly less prediction accuracy than those found at UHF (B, $\sigma(\Delta)$, P_{1c}, and P_{2c} of 1.51, 7.10, 0.65, and 0.87, respectively, for 63 samples) and at VHF (B, $\sigma(\Delta)$, P_{1c}, and P_{2c} of -0.93, 6.77, 0.72, and 0.90, respectively, for 61 samples).

In effect, there were only three assignments where a spurious response was predicted but not noted, namely, in assignments XIX-5 (-85, -75 dBm desired signal levels), XXII-4 (-83, -73 dBm desired signal levels), and XXIII-1 (-95, -85, -75 dBm desired signal levels). Seven cases are indicated since more than one desired signal level was involved. The predicted spurious response for assignment XIX-5 was calculated as a p = 2, q = 1 (+) mix. The predicted response for assignment XXII-4 was identified as a p = 3, q = 3 (-) mix, while the predicted spurious response for assignment XXIII-1 was calculated as a p = 2, q = 2 (-) mix. These mixes are defined by the following equation:

$$F_{sr} = \frac{pF_{lo} \pm F_{if}}{q} \qquad \text{(B-1)}$$

where

F_{sr} = frequency of the spurious response, in MHz

F_{lo} = local oscillator frequency, in MHz

F_{if} = intermediate frequency, in MHz

p, q = harmonic identifying integers.

The spurious response for assignment XIX-5 was predicted for the R-392/URR receiver, while the victim receivers for assignments XXII-4 and XXIII-1 were AN/ARC-102 types.

In terms of gross errors, spurious responses that were predicted and noted accounted for three cases while a response that was predicted but not measured resulted in only one case. It is not possible to determine whether the predicted-but-not-measured case was due to an error in estimated rejection level or coupling loss, or both. However, it is likely that coupling predictions, which include the effects of the BC-939-B coupler, involve more uncertainty than the rejection-level estimate.

Intermodulation

Intermodulation effects represent a rather complex problem of interpretation, since a number of independent parameters are involved. TABLE B-5 is a summary of the data presented in TABLE B-2. A larger sample size for certain interaction types would have been preferred, but this would have required a much more extensive test.

TABLE B-5

INTERMODULATION MEASURES

	B	σ(Δ)	P_{2c}	No. of Cases	Total % Cases
ALL IM	- .18	8.56	.82	120	34.8
RIM	-1.08	8.39	.84	107	31.0
PREDICTED AND NOTED					
2-SIG RIM	4.70	5.06	.92	13	3.8
2ND ORDER	2.69	3.01	1.00	9	2.6
3RD ORDER	-	-	-	0	0.0
5TH ORDER	9.23	5.77	.75	4	1.2
3-SIG RIM	4.46	3.45	1.00	8	2.3
3RD ORDER	4.46	3.45	1.00	8	2.3
5TH ORDER	-	-	-	0	0.0
PREDICTED BUT NOT NOTED					
2-SIG RIM	6.98	5.73	.86	7	2.0
2ND ORDER	10.46	5.39	.75	4	1.1
3RD ORDER	2.33	0.47	1.00	3	0.9
5TH ORDER	-	-	-	0	0.0
3-SIG RIM	5.16	5.07	.89	18	5.2
3RD ORDER	-	-	-	0	0.0
5TH ORDER	5.16	5.07	.89	18	5.2
NOTED BUT NOT PREDICTED					
2-SIG	-6.41	7.26	.73	37	10.7
3-SIG	-4.89	7.13	.88	24	7.0
TIM	7.27	5.96	.62	13	3.8
PREDICTED AND NOTED	7.07	6.49	.71	7	2.0
PREDICTED BUT NOT NOTED	7.50	5.26	.50	6	1.7

As in the case of the spurious interactions, three situations can occur, namely interactions where responses were:

1. predicted and noted
2. predicted and not noted
3. noted and not predicted.

As can be seen, a considerable number of cases fell in the latter two categories.

At the outset, it should be noted that, despite the fact that many of the cases did not fall in the first category (i.e., predicted and noted), the overall bias level (TABLE B-5) was essentially zero and $\sigma(\Delta)$ and P_{2c} values were of the same order of magnitude as those achieved for the overall tests. However, the large number of gross errors, discussed below, suggests that the mechanism requires additional consideration. We first address those cases which were noted but not predicted. These are listed in TABLE B-6.

Note the last column in the table. The expressions indicate possible combinations of frequencies which could have resulted in the measured interactions. Several situations are left blank; no explanations are apparent. Some of the interactions are considered by COSAM; some are not.

The expression of interest, in regard to RIM is:

$$f_o = A_{f1} + B_{f2} + C_{f3} \pm E \qquad \text{(B-2)}$$

TABLE B-6

INTERMODULATION INTERACTIONS NOTED, BUT NOT PREDICTED

Assignment	Desired Signal Level, dBm	Terminal Combinations	Possible Explanation of Interaction
I-4	-95,-85	1,5,6	
I-5	-55	4,6	RIM 4 $(3F_4-F_6)$
I-6	-75	4,5	RIM 4 $(3F_4-F_5)$
V-4	-95,-85	2,6	
VI-2	-77	1,5	
VI-3	-95,-85	2,5	
VI-4	-95,-85	2,6	
VI-5	-95,-85,-75	3,4,6	RIM 3 $(F_3+F_4-F_6)$
VI-6	-95,-85,-75	3,4,5	RIM 3 $(F_3+F_4-F_5)$*
VII-2	-65	1,3	RIM 3 $(2F_1-F_3)$ *
X-4	-95	2,6	
X-5	-55	2,4,6	RIM 4 $(F_2-2F_4+F_6)$
XI-1	-95,-85,-75	2,3,5	RIM 3 $(-F_2+F_3-F_5)$
XI-2	-95,-85,-75	1,3,5	RIM 3 $(-F_1+F_3-F_5)$
XI-5	-69	1,2,3	RIM 3 $(-F_1-F_2+F_3)$
XIII-1	-88,-78,-68	2,5	
XIV-5	-95,-85	1,3,4	
XIV-5	-95,-85	2,3,4	
XV-1	-95,-85,-75	2,4,6	
XV-1	-95,-85,-75	4,5,6	
XV-4	-95,-85,-75	2,6	
XVI-5	-85,-75	1,3,4	RIM 5 $(-F_1+2F_3+2F_4)$
XVIII-4	-95,-85,-75	2,6	
XVIII-4	-95,-85,-75	5,6	
XVIII-6	-95,-85,-75	4,5	
XIX-2	-76,-66	3,4	
XIX-4	-95,-85,-75	2,6	
XX-5	-85,-75	1,2	RIM 2 (F_1-F_2)[a]
XXI-5	-95,-85,-75	3,4	RIM 2 $(-F_3+F_4)$[a]
XXV-4	-95,-85,-75	1,2	

[a]Interactions considered by COSAM.

The coefficients in Equation B-2 may be positive or negative integers. The term f_o is the receiver frequency. E is generally set equal to a value somewhat larger than one half of the receiver IF bandwidth. Past experience indicates that the largest value of these integers, for most practical cases, is 2 or 3. There is evidence that they may, in some cases, be much larger. It should be noted, however, that high order (above the 5th) IM product levels are relatively small.

It is also possible that one or more of the coefficients in Equation B-2 is a fraction, e.g., 1/2, 1/3, 1/4, etc. This implies that a spurious emission of a transmitter (generated in the frequency multiplication process, used to produce the desired frequency) was of sufficient magnitude to combine with one or more other emissions and form a noticeable IM product. A compound number greater than one is also possible. Therefore, f_o, the receiver tuned frequency, may, in some cases, be one of the receiver IF's (f_{IF}). There is relatively little data on which to support a model for this interaction. Further, the frequency, f_o, may represent a spurious response. No known cases of this type have been noted.

Another more subtle situation can arise. If one reviews TABLE A-16 (see, e.g., interaction XIV-5) one may note that a single transmitter caused significant degradation, but that a group of transmitters (including the first transmitter) caused more degradation. This multiple effect may not be an IM interaction, but rather the effect of additional transmitter noise.

The above complexities are to be expected at sites using HF transmitters and receivers, where coupling losses are relatively

small. They are less likely to occur at higher frequencies, where coupling losses tend to be larger.

From a practical standpoint, it seems unlikely that a model could be constructed which considers every possible situation that may occur at a site which includes a large number of HF transmitters and receivers.

Knowledge derivable from the reported exercise (and previous tests in other frequency bands) can be used to suggest "fixes" which will essentially prevent the occurrence of the various interactions noted in this section. Briefly, it is not necessary, or cost effective, to model every possible multiple interaction. It is, however, necessary to understand the various mechanisms in the event that cases arise in the future where they must be considered in specific situations.

A limited attempt was made to identify all of the interactions outlined in TABLE B-6 which were caused by two or more transmitters but were not identified by the COSAM program as being an IM product. A more detailed effort would, ultimately, provide additional identifications, but the decision was made to limit the exercise.

TABLE B-7 lists the cases where IM was predicted but not noted. The most likely reason for this type of situation is underestimation of coupling loss.

TABLE B-7

INTERMODULATION INTERACTIONS PREDICTED, BUT NOT NOTED

Assignment	Desired Signal Level, dBm	Type of Intermod and Interacting Terminals
I-1	-95,-85,-75	RIM 5 (3,4,6)
I-2	-78,-68	RIM 5 (1,3,4)
II-1	-67	RIM 2 (3,6)
II-3	-95,-85,-75	RIM 2 (1,6)
III-5	-90,-80,-70	RIM 5 (1,4,6)
III-6	-67	RIM 5 (1,4,5)
IV-3	-95,-85,-75	TIM 3 (1,4)
V-1	-91,-81,-71	RIM 5 (3,4,6)
XIII-5	-95,-85,-75	RIM 3 (2,4)
XVIII-1	-89,-79,-69	RIM 5 (2,4,5)
XXV-1	-95,-85,-75	RIM 5 (2,5,6)
XXV-4	-95,-85,-75	TIM 3 (2,5)

In summary, a number of factors may have contributed to cases involving more than one emitter where differences between predictions and measurements were rather large. These are:

Over- or under-estimation of coupling loss. Effective on-tune input interfering power levels, termed P_{INO}, are proportional to the intermodulation order; e.g., $P_{INO} \propto (m + n)\, P_i$, if interfering input power levels are equal.[a] A coupling estimate as large as 10 dB, for example, would represent a difference of 30 dB for a 3rd-order interaction, a 50 dB difference for a 5th-order interaction, etc. SINAD differences would be smaller due to the receiver's limited dynamic range.

Effects of transmitter noise due to several emitters. The COSAM system accounts for additive transmitter noise effects, but does not identify emitters which have worse-than-average noise characteristics. Additional effort in this area is planned.

[a]See Equations C-30 and C-31.

IM interactions not considered by the current COSAM system. Fourth order, for example, has not been noted previously; a few of these cases are noted in TABLE B-6. The effects of spurious emissions and responses have also not been noted. Based on the findings in the VHF test (Reference 4) and in this HF exercise, it appears that the following IM orders should be considered (for RIM) in addition to those presently being considered.

$$f_{IF} = mf_1 \pm nf_2 \tag{B-3}$$

$$f_o = f_1 - 2f_2 \tag{B-4}$$

$$f_o = f_1 - f_2 - f_3 \tag{B-5}$$

$$f_o = 2f_1 + 2f_2 - f_3 \tag{B-6}$$

$$f_o = 3f_1 - f_2 - f_3 \tag{B-7}$$

$$f_o = 3f_1 - f_2 \tag{B-8}$$

$$f_o = f_1 - 2f_2 + f_3 \tag{B-9}$$

The list is formidable and an even larger list of 3rd-, 4th-, and 5th-order products could be given. IM calculations involve considerable computer time, and the fact that several of the above combinations are not likely to occur at all frequencies suggests that the capability to use any or all of the interactions should be optional.

Evaluation of Large Discrepancies

TABLE B-8 lists the 62 cases (of the total 345) where the absolute value of the difference between the measured SINAD and the predicted [illegible] n was greater than 10 dB.

TABLE B-8

EVALUATION OF LARGE DISCREPANCIES [$|S_M - \bar{S}_p| \geq 10$ dB]
(Page 1 of 2)

Interaction Identity	PD (dBm)	Type of Interaction	Notes	$S_M - \bar{S}_p$ Diff Between Meas. & Pred. Mean (dB)	Condition Error
II-3	-95	2 SIG-2ND	P	18.3	4
II-3	-85	2 SIG-2ND	P	12.0	2
III-1	-70	AS		-10.6	2
IV-3	-95	2 SIG-3RD (TIM)	P	12.9	3
IV-3	-85	2 SIG-3RD (TIM)	P	14.1	3
IV-3	-75	2 SIG-3RD (TIM)	P	11.0	3
IV-4	-85	2 SIG-3RD (TIM)	P	13.0	3
IV-4	-75	2 SIG-3RD (TIM)	P	19.7	3
VI-1	-75	SE	PN	-14.0	-3
VI-4	-95	2 SIG-APP	N	-11.1	-2
VII-4	-85	SR	PN	16.3	3
VII-4	-75	SR	PN	15.7	3
VII-5	-85	AS		11.0	2
VII-5	-75	AS		11.9	2
XI-1	-85	3 SIG-APP	N	-18.0	-4
XI-1	-75	3 SIG-APP	N	-27.5	-4
XI-3	-75	AS		-11.5	-3
XI-4	-95	AS		-11.0	-3
XI-4	-85	AS		-19.9	-4
XI-4	-75	AS		-19.9	-2
XI-6	-75	AS		-15.0	-3
XII-1	-85	AS		-15.8	-3
XII-1	-75	AS		-20.4	-3
XIII-6	-85	AS		-12.8	-3
XIII-6	-75	AS		-10.6	-2
XV-1	-85	3 SIG-APP	N	-13.0	-3
XV-1	-75	3 SIG-APP	N	-13.5	-1
XV-4	-95	2 SIG-APP	N	-15.4	-3
XV-4	-85	2 SIG-APP	N	-25.1	-4
XV-4	-75	2 SIG-APP	N,1	-25.9	-4
XVI-3	-75	3 SIG-3RD	PN	12.0	2
XVI-4	-85	AS		-11.6	-3
XVI-4	-75	AS		-19.7	-4
XVII-1	-85	AS		-10.1	-2
XVII-2	-78	AS		-10.6	-2
XVII-3	-85	AS	2	10.5	3

TABLE B-8

(Page 2 of 2)

Interaction Identity	PD (dBm)	Type of Interaction	Notes	$S_M - \bar{S}_p$ Diff Between Meas. & Pred. Mean (dB)	Condition Error
XVII-4	-68	AS		-10.2	-1
XVIII-1	-79	3 SIG-STH	P	14.0	3
XVIII-1	-69	3 SIG-STH	P	19.0	4
XVIII-3	-85	AS		-11.7	-3
XVIII-3	-75	AS		-12.9	-2
XVIII-4	-85	2 SIG-APP	N,1	-14.1	-3
XVIII-4	-75	2 SIG-APP	N,1	-13.3	-1
XIX-2	-66	2 SIG-APP	N	-13.4	-3
XIX-3	-75	AS		-12.1	-3
XIX-4	-95	2 SIG-APP	N	-10.8	-3
XIX-4	-85	2 SIG-APP	N	-14.7	-3
XIX-4	-75	2 SIG-APP	N	-13.1	-1
XIX-6	-75	AS		-15.8	-3
XX-1	-75	SR	PN	-14.2	-1
XX-2	-75	AS		11.2	2
XX-3	-95	AS		17.2	3
XX-6	-73	AS		-10.2	-3
XXII-4	-73	SR	P	15.4	3
XXIII-3	-95	AS	2	22.0	4
XXIII-3	-85	AS	2	18.0	3
XXIII-3	-75	AS		12.8	3
XXIV-1	-85	SE	PN	-11.2	-3
XXIV-1	-75	SE	PN	-19.9	-4
XXV-1	-75	3 SIG-STH	P	11.0	2
XXV-3	-82	2 SIG-STH	PN	11.0	2
XXV-3	-72	2 SIG-STH	PN,1	17.9	3

NOTES:

PN MAJOR INTERACTION PREDICTED AND NOTED.

P MAJOR INTERACTION PREDICTED BUT NOT NOTED.

N MAJOR INTERACTION NOTED BUT NOT PREDICTED.

1. Large anomaly between normal and Interferer Isolation subtest measured data for identical configurations.

2. Measured SINAD for a lower desired power level greater than corresponding SINAD for a higher desired power level.

Eleven of the cases had differences less than or equal to 11 dB. Five cases resulted in only a one-condition error while 13 of the 62 cases were in error by two conditions.

The positive values of dB and condition-error differences indicate that the measured SINAD ratio was greater than the mean prediction, resulting in a pessimistic bias. Negative values express the converse situation.

TABLE B-9 summarizes the results, noting the various interactions and whether they indicated too much predicted interference (+) or too little predicted interference (-).

Most of these large discrepancies are believed to be due to coupling prediction errors. As stated earlier, the coupling model standard deviation was 9.0 dB or greater. Uncertainties of this magnitude in coupling prediction will necessarily result in some IM cases with errors of 20 dB or greater. However, in spite of such large coupling uncertainties, only 13% of the cases resulted in gross errors, as defined.

Note on Population Composition

The significance of any statistical analysis is necessarily dependent on the sample size and the nature of the sample. Ideally, the selected sample will be representative of the real world with the result that conclusions drawn from the analysis will be applicable to the real world.

TABLE B-9

SUMMARY OF LARGE DISCREPANCIES

Interaction	Total (+)	Total (-)	Interactions
Spurious Responses (TOTAL)	3	1	4
SR Predicted and Noted	2	1	3
SR Predicted but not Noted	1	0	1
Spurious Emissions (TOTAL) (Predicted and Noted)	0	3	3
IM (TOTAL)	13	13	26
2-Signal, 2nd Order (Predicted But Not Noted)	2	0	2
2-Signal, 3rd Order TIM (Predicted But Not Noted)	5	0	5
2-Signal, 5th Order (Predicted and Noted)	2	0	2
3-Signal, 3rd Order (Predicted and Noted)	1	0	1
3-Signal, 5th Order (Predicted But Not Noted)	3	0	3
2-Signal, Noted But Not Predicted	0	10	10
3-Signal, Noted But Not Predicted	0	3	3
Adjacent Signal (TOTAL)	8	21	29
Noise	0	0	0
	24	38	62

TABLE B-10 reflects the distribution of measured SINAD values and predicted SPS values. The distributions are not uniform and are, in fact, denser at the extremes than at the center. As can be seen, only 28% of the SINAD cases lie between 5 and 12 dB.

Considerable effort would have been required in order to generate frequency assignments that would result in a uniform distribution of output SINAD values and would, in addition, provide approximately equal numbers of all of the types of interactions noted in TABLE B-2.

In operational situations, existing cosite assignments will probably provide SINAD ratios greater than 12-15 dB for a large percentage of possible interactions. For those cases where interference is expected (usually avoided by not activating certain transmitters simultaneously) most SINAD ratios will probably be below 4 dB. Similarly, most real-life assignments will not contain as many effects due to spurious responses and emissions and intermodulation as were deliberately inserted into the test assignments. Most cosite frequency assignments are made essentially at random with major emphasis on adjacent-signal separation.

In other words, typical situations represent reasonably clear-cut cases of degradation and/or no degradation. The chance of a marginal situation is rather remote.

Consequently, the distributions indicated in TABLE B-10 are probably more homogeneous in the middle range than would be expected in actual operating conditions. This feature was desirable to test the model over all possible ranges.

TABLE B-10

POPULATION DISTRIBUTION

Condition No.	Measured SINAD Values			Predicted SPS Values		
	SINAD (dB)	No.	%	SPS	No.	%
A	>18	39	11.3	.81-1.00	87	25.2
B	>12; ≤ 18	46	13.3	.61-.80	20	5.8
C	> 7; ≤ 12	60	17.4	.41-.60	19	5.5
D	> 4; ≤ 7	37	10.7	.21-.40	30	8.7
E	≤ 4	163	47.3	.00-.20	189	54.8

If, however, a more realistic population range had been employed, there would probably have been even more "bunching" at the extremes. And, since fewer spurious responses and emissions and intermodulation cases (the most difficult to predict) would be present, the number of gross errors (those involving more than two interference-condition errors or more than 10 dB between the measured value and the predicted mean) would probably be smaller than the number recorded in TABLE B-9.

COMMENTS ON MEASURED DATA ADEQUACY

The preceding analysis presupposes that all of the measured data were correct and accurate to within ±1 dB or better. Apparent prediction errors or large variations are assumed to be due to the analysis program rather than the measurements.

However, a review of the measured data, independent of the analysis, indicated numerous items that could either be explained by measurement inaccuracies, typographical errors or large variations in performance of specific equipments.

The requirement for interferer isolation determination resulted in 241 cases being measured.

Investigation of these data indicates the degree of repeatability achieved with the test configuration. Measured SINAD differences of 2 dB or less would be expected for a repeatable test. TABLE B-11 lists the distribution of measured SINAD value differences for all these repeated cases. The percentage that were repeatable, based on the 2 dB or less criterion, is 92.5%. 1.6% of the cases experienced differences of 7 dB or greater.

In general, COSAM component models are based on laboratory type measurements. The variations among equipments suggest that a minimum error of at least 5 dB will be inherent in any prediction model. This uncertainty is somewhat compensated for in COSAM by statistically varying desired signal, interfering signal, and ambient noise levels.

Several other cases could be cited involving possible measurement error. For example, several cases of "apparent" 2- and 3-signal IM which were not predicted by COSAM could not be attributed to any identifiable mix. If an error had been made in measuring any of the frequencies involved, this would have accounted for the fact that COSAM did not properly identify the interactions.

TABLE B-11

DISTRIBUTION OF REPEATED MEASUREMENTS
(241 Tests)

$\lvert SINAD_A - SINAD_I \rvert$, dB (See notes)	No.	%
0	182	75.5
1	28	11.6
2	13	5.4
3	8	3.3
4	5	2.1
5	0	0
6	1	.4
7	1	.4
8	1	.4
9	2	.8
10	0	0

NOTES:

$SINAD_A$ is the value measured during tests with all interferers on.

$SINAD_I$ is the corresponding value measured during interferer isolation tests.

If all of the anomalous situations referred to above had been eliminated from the validation analysis, COSAM predictions would have been even closer to measured values.

It is concluded that some measurement errors may have occurred and that, at best, the HF equipment performance was inconsistent during the test (see TEST RESULTS, APPENDIX A). These factors affected the results of the validation analysis to some extent but, in another sense, also indicated the range of uncertainty the analyst may expect in evaluating the performance of specific nomenclatures. Large variations can evidently be anticipated, validating

the requirement that a prediction model include a statistical description of the input parameters as well as a statistical description of output performance.

INTERPRETATION OF PREDICTED SPS VALUES

The analysis has shown that if the SPS value is greater than 0.9, the analyst can be reasonably certain (with confidence level greater than 0.85) that intolerable interference (i.e., a SINAD value less than 4 dB) will not occur. Similarly, if the SPS is less than 0.1, he can be reasonably certain (probability of 0.91) that good performance (i.e., SINAD values greater than 18 dB) will not occur. If at all possible, improvements to equipment and operational conditions should be suggested which will bring the scores above 0.9.

APPENDIX C

THE COSITE ANALYSIS MODEL (COSAM)

INTRODUCTION

COSAM is an automated system model used to evaluate the electromagnetic compatibility of a single site where a large number of transmitting and receiving communication equipments are employed. Such a "co-site" EMC analysis must take into account the close distances between antennas, and the high level of undesired signals present at receiver inputs and transmitter outputs.

THE $\left[S/(I+N)\right]_{ino}$ CONCEPT

The parameter $\left[S/(I+N)\right]_{ino}$ is calculated by the COSAM program for each receiver specified in the analysis. This parameter is defined as the effective input on-frequency signal-to-interference-plus-noise ratio resulting from any of, or the combined effects of, the five types of interactions predicted by COSAM. These interaction types, listed below, are calculated by COSAM for each receiver versus the transmitters specified in the analysis:

1. Adjacent signal.
2. Receiver intermodulation.
3. Transmitter intermodulation.
4. Receiver spurious response.
5. Transmitter spurious emission.

Three variables are involved. S is the desired signal power (P_d); N is the ambient noise power level (P_n); and I is the sum of

effective input on-frequency interference power levels $\left(\sum P_{ino}\right)$. P_{ino} is the effective input on-frequency interference power level due to a single interaction. The summation involves a conversion from dBm to watts; when the addition is made, the result is reconverted to dBm. We have:

$$\left[S/(I+N)\right]_{ino} = 10 \log_{10} \left[P_d/\left(P_n + \sum P_{ino}\right)\right] \qquad \text{(C-1)}$$

When P_d, P_n, and P_{ino} are expressed in watts the ratio is in dB.

In co-site situations, frequencies of interfering signals will not be equal to the desired signal (receiver) frequency. However, equations are supplied for each of the five interactions which convert input values of P_d (at f_o) and P_i (at f_i) to P_{ino} permitting conversion to $\left[S/(I+N)\right]_{ino}$. This can then be easily converted to $(S+I+N)/(I+N)$, commonly called SINAD, for the model output.

DEGRADATION CONSIDERATIONS

Operational degradation is a somewhat loosely defined term which implies relating such parameters as receiver output $S/(I+N)$ or $(S+I+N)/(I+N)$ ratios to measures that will be meaningful to users, designers, and analysts. One of the most commonly used measures is the articulation score, which is the percentage of a standard word list that can be recognized as a function of output (S/N) ratio.

The COSAM model computes the statistical distribution of the desired signal, the noise, and each P_{ino}. Since the anticipated output SINAD is therefore also statistical, an articulation score measure is used to select a SINAD threshold. The COSAM model then computes the probability of exceeding this threshold. This gives a

numerical "score" upon which the user may base his decision as to the seriousness of degradation to a system. A threshold value of 10 dB, which corresponds to an articulation score of approximately 70%, is commonly used.

COSAM provides three numerical scores, discussed in more detail below. See Figures C-1 and C-2. The upper performance score (UPS) is the probability of providing "adequate" or "good" performance if no interference is present. The system performance score (SPS) is the probability of adequate (or good) performance in the presence of interference. The relative performance score (RPS=SPS/UPS) provides the user with another measure which, in conjunction with the other scores, gives additional understanding of receiver performance. For example, if the SPS were 0.4, one would predict poor performance. However, if the UPS were also 0.4, RPS = 1.0, and it can be seen that the inadequate desired signal would be the major problem.

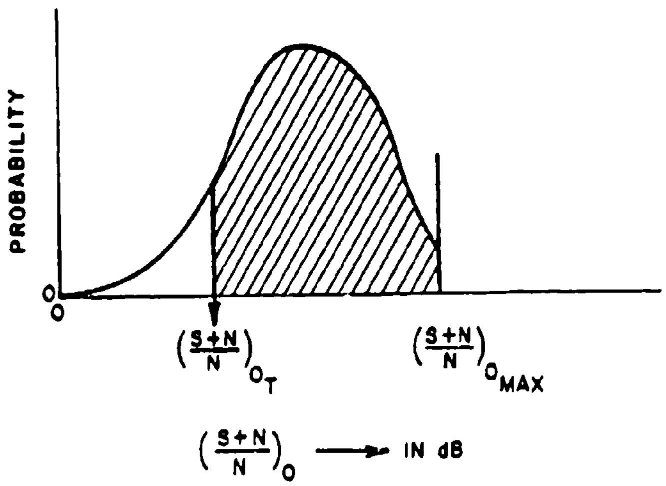

Figure C-1. Representative distribution of $\left(\frac{S+N}{N}\right)_O$ for a given receiver (upper performance score calculation). (See notes, Figure C-2.)

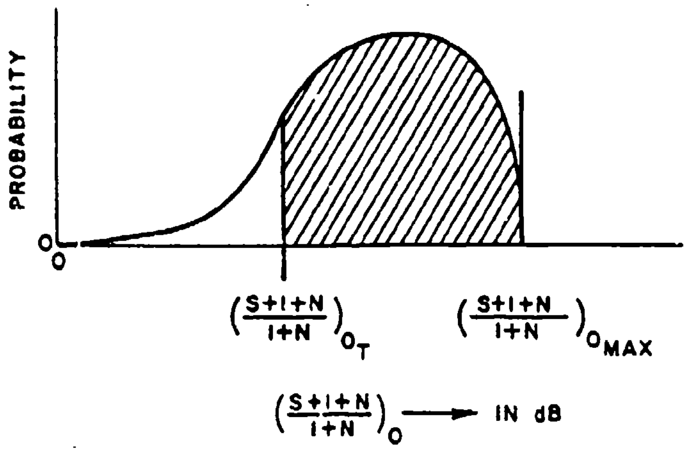

Figure C-2. Representative distribution of $\left(\frac{S+I+N}{I+N}\right)_O$ for a given receiver (system performance score calculation).

Notes:

1. $\left(\frac{S+N}{N}\right)_{O_T}$ and $\left(\frac{S+I+N}{I+N}\right)_{O_T}$ are threshold values of signal-plus-noise to noise, and signal-plus-interference-plus-noise to interference-plus-noise ratios, respectively.
2. The SCORES from 0 to 1 are the cross-hatched area divided by the total area for each curve.
3. To account for variable dynamic ranges the maximum values of $\left(\frac{S+N}{N}\right)_O$ and $\left(\frac{S+I+N}{I+N}\right)_O$ are specified by the user. Calculated values above the maximum appear at the maximum.

DEGRADATION COMPUTATIONS

Receiver detector transfer function equations are used to convert input S/(I+N) ratios to output S/(I+N) ratios. The following

relationships have been tentatively established (the heading for each case lists the desired signal first and the undesired signal second):

AM • AM

$$\left(\frac{S}{I+N}\right)_o = \left(\frac{S}{I+N}\right)_{ino} - 8 \qquad \text{(C-2)}$$

AM • NOISE

$$\left(\frac{S}{I+N}\right)_o = \left(\frac{S}{I+N}\right)_{ino} + 10 \log BW_{MHz} + 11 \qquad \text{(C-3)}$$

FM • FM

$$\left(\frac{S}{I+N}\right)_o = \left(\frac{S}{I+N}\right)_{ino} + 5 \qquad \text{(C-4)}$$

FM • NOISE

$$\left(\frac{S}{I+N}\right)_o = \left(\frac{S}{I+N}\right)_{ino} + 2 \qquad \text{(C-5)}$$

SSB • SSB AND SSB • NOISE

$$\left(\frac{S}{I+N}\right)_o = \left(\frac{S}{I+N}\right)_{ino} \qquad \text{(C-6)}$$

CALCULATION OF MEAN POWER LEVELS

As mentioned above, equations are used to convert off-tune interfering powers to on-tune mean P_{ino} values for the five types of interference interactions considered. In order to use the equations on the next page, the power present at a victim receiver due to each interfering transmitter must be calculated. COSAM calculates coupling loss by one of two methods depending upon the cosite

installation. If a ground or ship installation is being analyzed one method is used. If, on the other hand, the installation is an aircraft, a second method must be used so that coupling around the aircraft fuselage may be considered. Coupling loss, as defined below, includes the gain of the antennas as well as the space loss between antennas.

SUMMARY OF APPLICABLE COUPLING MODELS-EXCLUDED MISMATCH LOSSES

Ship and Land Coupling Loss

CONFIGURATION	MODEL	
Whip-to-whip	$C_p = -2G_{WHIP} + MAX\left[L_{FS}, L_{GW}\right] + \sin^2\theta\left[-50 + 20\log fd\right]$	(C-7)
Whip-to-horizontal dipole	$C_p = -G_{WHIP} - G_{DIPOLE} + MAX\left[L_{FS}, L_{GW}\right] + \sin^2\theta\left[-50 + 20\log fd\right] + 14\left[1-\sin\theta\right]^2$	(C-8)
Dipole-to-dipole (equal heights)		
Parallel orientation	$C_p = -2G_{DIPOLE} + MAX\left[L_{FS}, L_{GW}\right]$	(C-9)
Perpendicular orientation	$C_p = -2G_{DIPOLE} + MAX\left[L_{FS}, L_{GW}\right] + 14$	(C-10)
End-to-end orientation	$C_p = -2G_{DIPOLE} + MAX\left[L_{FS}, L_{GW}\right] + 20\log fd - 50$	(C-11)
45° orientation	$C_p = -2G_{DIPOLE} + MAX\left[L_{FS}, L_{GW}\right] + 3$	(C-12

where MAX L_{FS}, L_{GW} is the larger of the two losses calculated by:

$$L_{FS} = -37 + 20 \log fd \tag{C-13}$$

and

$$L_{GW} = -14 - 15 \log h_1' h_2' + 40 \log d \text{ (ft.)} \tag{C-14}$$

where

h_1', h_2' are "effective" heights, given by:

$$h' = \sqrt{h_0^2 + h^2} \tag{C-15}$$

where

h = the structural height (relative to the feed point), in feet

h_o = the minimum effective height, in feet

The formulas for h_o apply to the type terrain considered in the test. A more extensive set of formulas is given in Reference 19, on the EPM-73 propagation model.

$\log h_o$ = $1.5 \log f + 3.45$ if $1 \leq f \leq 20$ MHz (C-16)

= $-1.3 \log f + 3.2$ if $f > 20$ MHz for vertical polarization

h_o = 0 if $f > 1$ MHz for horizontal polarization (C-17)

C_p = mean coupling loss between the two antennas, (dB) (C-18)

G_{WHIP} = gain in dB of a whip antenna

G_{DIPOLE} = gain in dB of a dipole antenna

d = the distance between antennas, in feet

f = the frequency of the transmitted signal, in MHz

θ = the vertical angle between antenna positions in degrees (See Figure C-3)

λ = wavelength associated with the frequency at which the coupling is being calculated.

Each antenna location is identified by its X, Y, Z coordinates (in feet). An example is given in Figure C-3, illustrating the computation of θ:

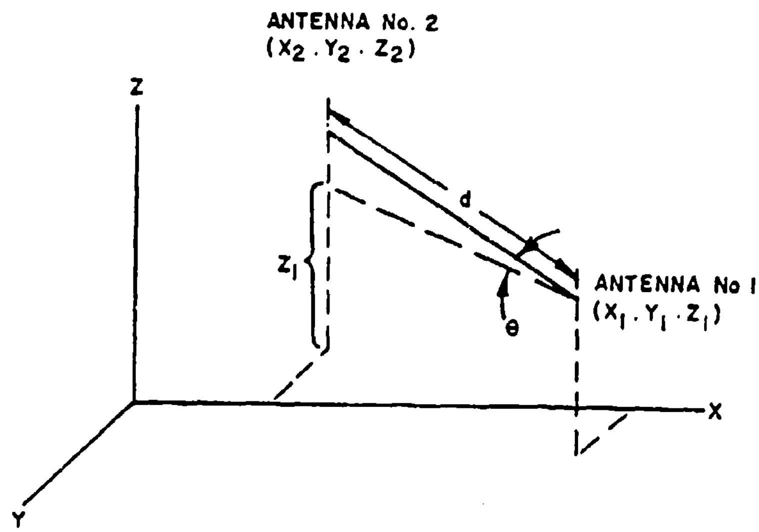

Figure C-3. Antenna coordinate system for shipboard and land configurations.

$$\theta = \arc \sin \frac{Z_2 - Z_1}{d} \qquad \text{(C-19)}$$

$$d = \sqrt{(X_2-X_1)^2 + (Y_2-Y_1)^2 + (Z_2-Z_1)^2} \qquad \text{(C-20)}$$

The statistical distribution of Equations C-7 through C-12 are assumed to be log normal and a value of standard devi..ion is supplied.

AIRCRAFT COUPLING LOSS

The expression for coupling loss on an aircraft assumes that antennas are on or above a perfectly conducting cylindrically or conically shaped airframe. The geometry of the airframe is depicted in Figure C-4. Some of the features are:

1. Raised antennas on stabilizer only
2. Cylindrically shaped body
3. Conically shaped tail section.

The expression for mean coupling loss is:

$$C(1,2) = -G(1)-G(2)+37.9+20 \log_{10} (df)+CF \qquad \text{(C-21)}$$

where

$G(1), G(2)$ = antenna gains (dB)

d = shortest distance in feet along the surface of the cylinder between the antennas (Figure C-5)

$$= \left[Z^2 + \left(\frac{\alpha\theta}{57.3} \right)^2 \right]^{\frac{1}{2}} \qquad \text{(C-22)}$$

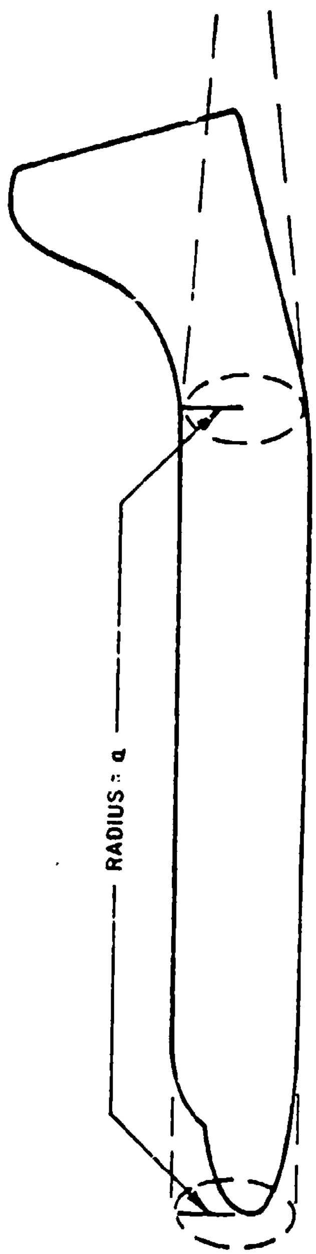

Figure C-4. Airframe geometry, assuming a combined cylindrically and conically shaped fuselage.

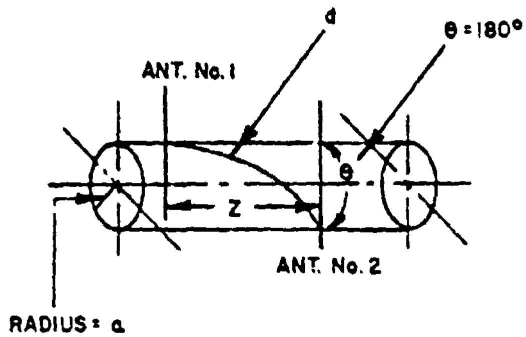

Figure C-5. Illustration of cylindrical terms.

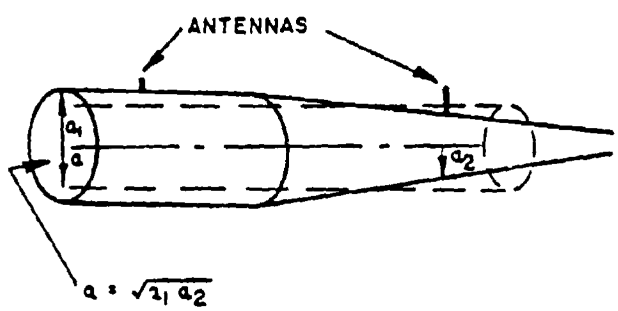

Figure C-6. Geometric mean cylinder.

f = frequency in MHz

α = radius of the cylindrical airframe in feet. If the aircraft is conical, $\alpha = \sqrt{\alpha_1 + \alpha_2}$, the geometric mean radius. (See Figure C-6).

CF = curvature factor which is a function of the variable y

$$y = 7.64 \times 10^{-4} \left[\frac{(\alpha/\lambda)\theta^2}{d/\lambda}\right] \qquad \text{(C-23)}$$

θ = the angle in degrees separating two planes that contain the longitudinal axis and the transmitting and receiving antennas, respectively

d = the distance in feet separating the projections of the transmitting and receiving antennas on the longitudinal axis

λ = wavelength in feet of the transmitted frequency.

A curve of y versus the curvature factor, CF, is used in the computation of path loss due to curvature around the cylinder. A special case of coupling is also considered. This is illustrated by a raised antenna (e.g., on a stabilizer) which is not line-of-sight with an antenna on the airframe. The minimum separation distance between the antennas is the sum of the straight line portion from the raised antenna to a tangent point on the cylinder plus the curved helical distance from the tangent point to the antenna on the cylinder.

The statistical distribution for Equation C-21 is also assumed to be log normal and a standard deviation value is supplied.

ANTENNA COUPLERS

The off-frequency rejection loss $\beta(C)$ due to antenna couplers is assumed to be that of N cascaded single-pole Butterworth band-pass filters and is given as follows:

$$\beta(C) = 10\ N\ \mathrm{Log}_{10}\left[1 + Q^2\left(\frac{f_o + \Delta f}{f_o} - \frac{f_o}{f_o + \Delta f}\right)^2\right] \qquad \text{(C-24)}$$

where

N = the number of tuned stages

Q = the quality factor or ratio of reactance to resistance of the circuit

f_o = tuned frequency of the circuit (MHz)

Δf = operating frequency minus f_o (MHz).

POWER LOSS COMPUTATION

To compute the mean received power at the input to the receiver (R_2) due to a single interfering transmitter (T_1) the following is used:

$$\bar{P}_r = \bar{P}_o\ (T_1) - \beta(C_1) - \bar{C}(1,2) - \beta(C_2) \qquad \text{(C-25)}$$

where

$\bar{P}_o$ = mean transmitter power output, in dBm

$\bar{P}_r$ = mean receiver power, in dBm

The variance (σ^2) of the P_r distribution is:

$$\sigma^2 (P_r) = \sigma^2 (P_o) + \sigma^2 |C(1,2)| \tag{C-26}$$

Losses of all significant paths are checked. For example, if T_1, T_3, and R_2 form a third-order IM triplet (discussed below), such that:

$$2f_1 - f_3 = f_2 \tag{C-27}$$

we say that a transmitter IM (TIM) product as well as a receiver IM (RIM) product will be formed. Further, T_1 is the "victim" transmitter in the TIM triplet and T_3 is the interfering transmitter.

To compute the mean TIM power at R_2 we must first compute the power at T_1 due to T_3, using Equation C-25. Briefly, a new product is said to be generated by T_1 at frequency f_2. Equation C-25 is then used again; however, this time Δf will be $f_2 - f_1$ and $f_o = f_1$. $\overline{\beta}(C_2)$ will be assigned a nominal value of 1 dB to account for coupler insertion loss.

Computation of mean RIM power levels at f_1 and f_2 will involve consideration of the paths from each transmitter to the receiver.

If T_1 has a spurious emission, Equation C-25 is employed in the same manner as in the case of a TIM product. Adjacent-signal and spurious-response computations also employ Equation C-25 as indicated.

COMPUTATION OF P_{ino} VALUES

Adjacent Signal Interference

The equation for the mean value of the effect[illegible] input on-frequency interference power level from an adjacent [illegible] is:

$$P_{ino} = P_i - \beta_{eff} + (1 - M)(P_d - R_s - S) \qquad \text{(C-27)}$$

where

P_i = input undesired power, in dBm

β_{eff} = effective off frequency rejection (due to Δf), in dB

P_d = input desired power, in dBm

M = a value of the slope $\Delta P_1/\Delta P_d$

= 1.0, $P_1 < P_{ib}$

< 1.0, $P_1 > P_{ib}$

R_s = receiver sensitivity, in dBm

P_{ib} = a specified interfering power break point.

Values for β_{eff}, M, P_{ib}, and R_s are obtained from equipment spectrum signature measured data.

SPURIOUS RESPONSES

The expression for spurious response calculations is:

$$P_{ino} = (1-q)\, R_s + q\,(P_i - \beta_{sr}) \qquad \text{(C-28)}$$

where

P_{ino} = the effective on-tune interference power, dBm

P_i = input undesired power, dBm

R_s = receiver sensitivity, dBm

β_{sr} = effective spurious response rejection, dB

q = a positive integer which represents the harmonic of the spurious frequency.

Note that if q = 1, P_{ino} is simply $\overline{P}_i$ - $\overline{\beta}_{sr}$. However, if q = 2, an increase of 10 dB in P_i will result in an increase of 20 dB in P_{ino}. Limited measured data supports this hypothesis for the p = 2, q = 2 response. Digital equations are used in COSAM to determine the various receiver IF and local oscillator (LO) frequencies as a function of tuned frequency. The spurious response frequency is then calculated as a function of the IF and LO frequencies.

SPURIOUS EMISSIONS

The expression to compute the spurious emission power at the receiver takes the form:

$$P_{ino} = P_t - \beta_{se} - \beta(C_t) - C_{tr} - 1 \qquad \text{(C-29)}$$

where

P_{ino} = the effective on-tune interference power, dBm

P_t = transmitter power, dBm

β_{se} = effective spurious emission rejection, dB

$\beta(C_t)$ = off-frequency rejection due to the transmitter coupler, dB

C_{tr} = coupling loss between transmitter and receiver due to antenna gains and path loss, in dB.

The value of 1 dB represents the insertion loss of the receiver coupler.

TRANSMITTER INTERMODULATION

The transmitter intermodulation power is given by the equation:

$$P_{im} = mP_v + n(P_i - \beta_{vi}) - K_{m,n} - \beta_{vr} \qquad \text{(C-30)}$$

where

P_{im} = power level in dBm of the IM product at the transmitter at frequency f_{im}

P_v = output power level in dBm of the victim transmitter signal at f_v

P_i = received power level in dBm of the interfering transmitter signal at f_i

β_{vi} = off frequency rejection in dB, a function of frequency difference between f_v and f_i and the victim transmitter output selectivity

$K_{m,n}$ = transmitter conversion loss term for the m+n order case

β_{vr} = off frequency rejection in dB, a function of the difference between f_v and f_r where $f_r \approx f_{im}$, and f_r is the tuned frequency of a victim receiver

m,n = integers

f_{im} = $mf_v - nf_i$

Values for $K_{2,1}$, $K_{3,2}$ and $K_{4,3}$ have been computed from spectrum signatures.

RECEIVER INTERMODULATION

The receiver intermodulation power is:

$$P_{im} = m(P_v - \beta_{vr}) + n(P_i - \beta_{ir}) - K_{m,n} \qquad \text{(C-31)}$$

where

P_{im} = power, in dBm, of the intermodulation product produced in the receiver

m,n = integers (same as Equation C-30)

P_v, P_i = power level, in dBm, of undesired signals

β_{vr}, β_{ir} = off-frequency rejection in dB, a function of the difference between undesired frequencies and receiver tuned frequency (f_r), where $f_r \simeq f_{im}$

f_r = $mf_v - nf_i$

$K_{m,n}$ = receiver RF amplifier or first mixer conversion loss

Values of $K_{1,1}$, $K_{2,1}$, $K_{3,2}$, and $K_{4,3}$ for the first mixer, and $K_{1,1}$, $K_{2,1}$, $K_{3,2}$ and $K_{4,3}$ for the RF amplifier, as well as β curves, have been computed from spectrum signature data.

STATISTICAL METHODS

Application of Monte Carlo Techniques

Each of the five interactions results in intermediate predicted distributions of P_d, P_i and P_n at the input to the receiver. In order to account for certain non-linearities in the receiver, specific power break-points have been specified in the adjacent signal and receiver intermodulation equations. For each equation, if the interfering power level exceeds the break-point, one constant ($M < 1$ or $K_{m,n}$, respectively) is used; if it does not, another constant ($M = 1$ or $K_{m,n}$, respectively) is used.

It is anticipated that the P_i distributions will frequently include values above and below the break-point(s). Consequently, a Monte Carlo procedure is used to select a single P_i value from the computed distribution by employing a random number generator and, depending on the value, the appropriate equation is selected. The process is then repeated many times to compute trends in the behavior of P_{ino} and $(S/I+N)_{ino}$.

In brief, one receiver is selected and an interaction table is examined to determine which transmitters are potentially significant. Then, for each interaction, the appropriate P_i, P_d and other parameter distributions are selected and a single value chosen from each by means of a random number generator.

A single value of P_{ino} is computed from these values, the next interaction is considered, using the same points, as applicable, and so on. This process is termed a "run." Then, for the same receiver, approximately 1,000 runs are performed, eventually resulting in a predicted $[(S+I+N)/(I+N)]_o$ output distribution. Each receiver is considered in the same manner.

COMPUTATION OF $[S/(I+N)]_{ino}$

Each run (of the many runs per receiver) contains a list of computed P_{ino} values. TABLE C-1 illustrates some typical results.

TABLE C-1

TYPICAL P_{INO} OUTPUT VALUES

RECEIVER NO. 1					
Trans. No.	Type	Run No. 1	Run No. 2	Run No. 1000	P_{INO}
No. 2	ADJ. SIG.	-120	-125	-123	-122
No. 3	ADJ. SIG.	-100	-104	-102	-103
No. 4	ADJ. SIG.	-85	-90	-87	- 89
No. 5	SPUR. RESP.	-130	-124	-126	-127
No. 6	SPUR. EMISS.	-125	-130	-128	-128
No. 7	3 rd	110	-112	-114	-112
No. 8	TIM				
No. 7	3 rd. ORDER	-100	- 93	- 98	- 95
No. 8	RIM				
	ΣP_{INO}				
P_d		-74	-78	- 76	- 75($\bar{P}_d$)
P_n		-108	-112	-110	-110($\bar{P}_n$)

Each column in TABLE C-1 contains a list of P_{ino} values for each run. The last column contains the mean value of P_{ino} due to each interaction. The program considers each run separately and computes the sum of P_{ino}. Also included are values of P_d and P_n. These distributions are not computed by COSAM. They are assumed for each problem and may be changed for different situations. $[S/(I+N)]_{ino}$ is then computed using Equation C-1.

OUTPUT

A distribution of $[S/(I+N)]_o$ values is determined using the appropriate transfer function (Equations C-2 through C-6). This

distribution is then transformed to a SINAD distribution as follows:

$$\begin{aligned} \text{SINAD} &= [(S+I+N)/(I+N)]_o \text{ dB} \\ &= 10 \log_{10}\left[1+10^{0.1[S/(I+N)]_o}\right] \text{dB} \end{aligned} \qquad \text{(C-32)}$$

After the computation of each receiver's degradation scores (Figures C-1 and C-2) a print is given summarizing the results of the interference analysis. The average P_{ino} values for each interference situation are given along with the three degradation scores. A plot of the SINAD distribution is also printed.

After all receivers have been examined, a final print lists all receivers and their associated scores.

APPENDIX D

R-388 RECEIVER ANALYSIS

PARAMETER MODELING

A summary of the analysis of the R-388 and example calculations are presented The objectives were to arrive at values for the COSITE FILE parameters, used by the COSAM program, and to employ these in the SINAD predictions. A comparison of the resulting predictions with measured values for interactions involving this receiver are also included. Most of these parameters are normally estimated from spectrum signature data. No spectrum signature has been performed on an equipment of this nomenclature, however, and the parameters were ascertained from equipment manual descriptions, manufacturer's tube specification sheet data and ECAC laboratory nonlinear (spurious) response measurements of a breadboarded mixer circuit. Mathematical techniques required for nonlinear response analysis are described in an ECAC Technical Note.[10]

On Figure D-1 is a sample sheet of the COSITE FILE printout record for the R-388, characteristics band 4 (R-388-4). The R-388 is a difficult receiver to model in that its tuning range (0.5 to 30.5 MHz) is comprised of 30 bands, each of which requires a separate record. The analysis of band 4 (3.5 to 4.5 MHz) is described in detail. These are covered in the order in which they appear on Figure D-1. In addition, the frequency conversion schemes of the receiver were analyzed. The resulting frequency rules, used in the SINAD predictions, were recorded.[11]

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[10] Maiuzzo, M., *Nonlinear Circuit Theory Applied to AM-DSB Receivers,* ECAC-TN-75-013, May 1975.

[11] ECAC Memorandum by ACOP-C/Gawthrop, Subject: "Frequency generation rules for the R-388/URR receiver as entered in COSAM for use in the HF Integration Task," 2 January 1975.

RECEIVER RECORD

SYSTEM NAME	COMPONENT NAME	EQT TYPE	TUNING RANGE IN MHZ	CHAN WIDTH IN MHZ	MOD TYPE	SENS DBM	SD SENS DB	BANDWIDTH MHZ	SD BANDWIDTH	NO OF IF STAGES
R-388-4	R-388-4	R	3.50- 4.50	.001	A3	-103.0	1.60	.006	6.000	2

FIRST IF MHZ	SECOND IF MHZ	THIRD IF MHZ	FIRST LO POS	SECOND LO POS	THIRD LO POS	FREQ RANGE C1 MULT MHZ	C1 MULT	FREQ RANGE C2 MULT MHZ	C2 MULT	MULT NO
1.50- 2.50	.50- .50	.00- .00	ABOVE	ABOVE		3.5- 4.5	1.000	.0- .0	.000	37

SPUR RES ΔF FORMULAS	N	REJECT DB	SPUR RES ΔF FORMULAS	N	REJECT DB	SPUR RES ΔF FORMULAS	N	REJECT DB	SPUR RES ΔF FORMULAS	N	REJECT DB	SPUR RES ΔF FORMULAS	N	REJECT DB
2*X1	1	100.5	3*X1/2-X4/2	2	43.2	4*X1/3-X4/3	3	123.4	X4	1	111.1	X1/2	2	118.0
3*X1/4-X4/4	4	63.6	6*X1/5-2*6/5	5	70.1	7*X1/6-X4/3	6	121.4	X1+X2/2-X5	2	104.5			

SD REJECT VALUE DB	ADJ SIG URPT DBM	SLOPE ΔPI/ΔPO	ΔF1 MHZ	REJECTION DB	ΔF2 MHZ	REJECTION DB	REJECTION SLOPE DB/OCTAVE	REJECT SD DB	IM BREAK POINT DBM
6.0	-35.0	.33	.010	63.0	.060	76.0	18.00	10.0	-12.0

INTERMOD LOSS FACTOR K1,1	INTERMOD LOSS FACTOR K2,1	INTERMOD LOSS FACTOR K3,2	INTERMOD LOSS FACTOR K4,3	INTERMOD LOSS FACTOR K'1,1	INTERMOD LOSS FACTOR K'2,1	INTERMOD LOSS FACTOR K'3,2	INTERMOD LOSS FACTOR K'4,3
22.8	-48.7	-124.2	-200.6	22.8	29.4	38.8	42.3

NO OF STAGES	4	SD IM LOSS FACTORS
3	52.0	6.0

VARIABLE DEFINITION

X1 - FIRST INTERMEDIATE FREQUENCY
X2 - SECOND INTERMEDIATE FREQUENCY
X3 - THIRD INTERMEDIATE FREQUENCY
X4 - FIRST LOCAL OSCILLATOR FREQUENCY
X5 - SECOND LOCAL OSCILLATOR FREQUENCY
X6 - THIRD LOCAL OSCILLATOR FREQUENCY
X7 - CRYSTAL FREQUENCY OF FIRST LOCAL OSCILLATOR

Figure D-1. Cosite file record for the R-388 receiver, band 4.

RECEIVER SENSITIVITY AND STANDARD DEVIATION

On Figure D-2 is a plot of receiver sensitivity in microvolts versus tuned frequency.[12] Note that from 3.5 to 4.5 MHz the sensitivity lies between 2.9 μV and 3.1 μV. The sensitivity, in dBm, measured by introduction of a fifty-ohm source, may be computed by:

$$R_s = 10 \log r_s = 20 \log \left(\gamma \frac{50 + Z_R}{Z_R}\right) - 113 \qquad \text{(D-1)}$$

where

R_s = receiver sensitivity, in dBm

r_s = receiver sensitivity, in milliwatts

Z_R = receiver input impedance at f_o

f_o = receiver tuned frequency

γ = receiver sensitivity in μV (from Figure D-2)

If we assume that the receiver input impedance at f_o is fifty ohms:

$$R_s = 20 \log \gamma - 107 \text{ dBm} \qquad \text{(D-2)}$$

This gives us, for γ = 3.0 μV, a receiver sensitivity of -97 dBm. However, more accurate estimates are possible. A value of R_s = -103 dBm (at f_o = 4 MHz) was arrived at by linear circuit analysis techniques described below.

Figure D-3 contains a simplified circuit diagram of the receiver input stage applicable to band 4 operation.[13] The input impedance

[12]NAVSHIPS 92324, "Communications Receiver 51J-4 (Navy Model R-388A/URR)."

[13]Department of the Army Technical Manual, TM-11-854, "Radio Receiver R-388/URR."

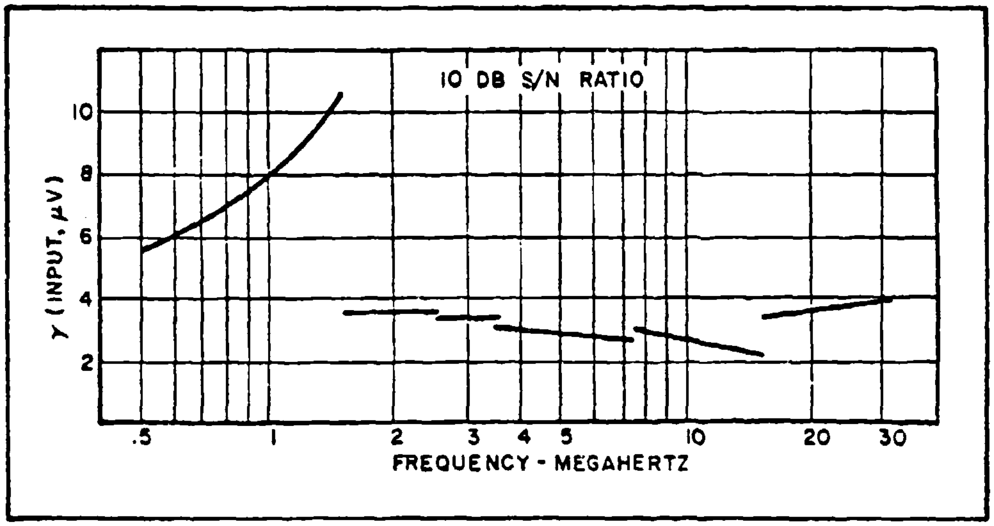

Figure D-2. R-388 sensitivity curve.

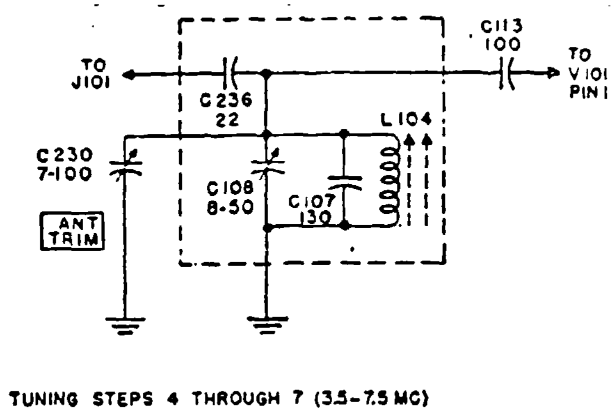

Figure D-3. RF input circuit schematic diagram.

of this stage was computed in the following manner. Medhurst's method[14] was employed to find the minimum inductance (slug removed) of L104. A physical description of L104 was obtained from the parts list of Reference 13. The resistance of the coil at 7.5 MHz (minimum inductance for this permeability-tuned circuit) was computed employing Medhurst's method and an assumption of tight windings. Based on conversations with J. Vanderheid, a radio design engineer at Collins, Cedar Rapids, Iowa, it was assumed that coil resistance remained constant from 3.5 to 7.5 MHz. Capacitor C230 was assumed to be 50 pF. The value of C108 was computed for circuit resonance at 7.5 MHz, and this value was held constant. The value of L104 for circuit resonance at 4 MHz and the receiver input impedance were computed. Substitution of γ and this value of Z_R into Equation D-1 yielded a sensitivity of approximately -103 dBm. Additional calculations at tuned frequencies from 3.5 to 4.5 MHz resulted in a standard deviation of 1.6 dB.

SPURIOUS RESPONSES

Spurious-response rejections were calculated according to the following formula (Reference 10, page 48).

$$\beta_E = \beta_2(\omega_I) + \frac{1-q}{q}\left[R_s + G_{2,0}(\omega_o) - 6\right] + \frac{1}{q}\left[-10 \log q + B_{1,1} - B_{p,q}\right] \mathrm{dB} \qquad \text{(D-3)}$$

where

β_E = receiver rejection to a particular spurious response, dB

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[14]Wireless Engineer, "H. F. Resistance and Self Capacitance of Single Layer Solenoids" by R. G. Medhurst, February and March, 1947.

$\beta_2(\omega_I)$ = 20 $\log_{10} \hat{\beta}_2(\omega_I)$, dB

$\hat{\beta}_2(\omega_I)$ = off-frequency rejection at the mixer input that would be experienced by a signal at ω_I. [i.e., $g_2(\omega_o)/g_2(\omega_I)$]

$G_{2,0}(\omega_o)$ = value of $G_2(\omega_o)$ present during minimum signal conditions (no AGC).

$G_2(\omega)$ = 20 $\log_{10} g_2(\omega)$, in $dB\left(\frac{V}{\sqrt{mW}}\right)$

$g_2(\omega)$ = ratio of the mixer signal grid voltage to the square root of the available power at the receiver input, in $V/\sqrt{mW}$, a linear transfer characteristic of the receiver. Includes the linear gain of the r.f. amplifier (a_1), thus a function of the AGC.

q = harmonic number of signal carrier frequency contributing to spurious response

R_s = 10 log r_s, in dBm

r_s = receiver sensitivity, in milliwatts, as measured in test CS101, MIL-STD-449D

$B_{i,j}$ = 20 $\log_{10} b_{i,j}$

$b_{i,j}$ = equivalent i^{th} order coefficient of the Taylor series representing the p=j transfer function of the mixer, i = 1, 2, 3,...... and j = 0, 1, 2,...... . Without the second subscript, j is assumed to be 1.

The equation was computed for all combinations of p and q from 1 to 9. These computations required estimates of the following parameters in the described manner.

1. β_2 (ω_I): This was computed at each spurious frequency, employing linear circuit analysis techniques. Equivalent circuits were formulated. Inductance and capacitance values were arrived at in the same manner as described above. Stray (or parasitic) capacitance for the amplifier was estimated from manufacturers' tube specification data. The resistance of the inductor L107 operating in band 4 was computed in two ways, which interestingly yielded the same result. One way is described above for the impedance calculation. The other assumes that the reactance of the top coupling in the double-tuned circuit (DTC) is equal to the equivalent parallel coil resistance. This assumption implies that the DTC is "critically" coupled as was suggested by J. Vanderheid.

2. $G_{2,0}$ (ω_o): Linear circuit analysis techniques were also applied. The gain of the RF amplifier was computed from a pentode model[15] using operating voltages from the equipment manual and from specification sheet data.

3. $B_{i,j}$: These coefficients were obtained by constructing a breadboarded mixer circuit similar (although with resistive load) to the one in the receiver, and measuring the spurious responses. It was observed that the local oscillator harmonics were not a factor in the measurements.

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[15]Bonnett, D. and Maiuzzo, M., *Prediction of Nonlinear Effects in a Pentode Amplifier*, ECAC-TN-75-014, May 1975.

ADJACENT SIGNAL PARAMETERS

The adjacent-signal parameters indicated in Figure D-1 were obtained by employing the techniques described in Reference 10, as follows:

1. Slope ($\Delta P_I/\Delta P_d$): Computed as

$$M = - \frac{\Delta A_1}{\Delta P_d} \tag{D-4}$$

where ΔP_d is the dynamic range of the AVC (Reference 12) and the corresponding ΔA_1 is the voltage gain of the amplifier (normal bias conditions for no signal input).

2. Adjacent Signal Break Point (P_{ib}) (from Reference 10):

$$P_{ib} = 1/2\ (B_1 - B_3) - G_{2,0}\ (\omega_o) - 8 \text{ dBm} \tag{D-5}$$

where

B_i is 20 log b_i

b_i is an equivalent i^{th} order coefficient of the Taylor series representing the p=1 transfer function of the mixer (i=1,2,...). Computed from mixer breadboard measurements described above.

3. β_{EFF}: The effective off-frequency rejection of an adjacent interference signal, usually obtained from spectrum signature data and stored in the COSITE File; may include effects of transmitter noise and receiver linear and nonlinear mechanisms, in dB. From β_{EFF} the parameters $\Delta F1$, $\Delta F2$, their corresponding rejection values and rejection slope are determined. An ASI curve was constructed from the above parameters, along with an IF selectivity curve (Reference 12).

This was done according to the procedure described in Section 3 of Reference 10. The result is shown in Figure D-4. A curve representing β_{EFF} was constructed from this curve by extracting data points for a constant value of P_d (equal to $R_s + 5$) and plotting these versus ΔF (β_{EFF} is the value of P_I at ΔF relative to the value of P_I at $\Delta F = 0$).

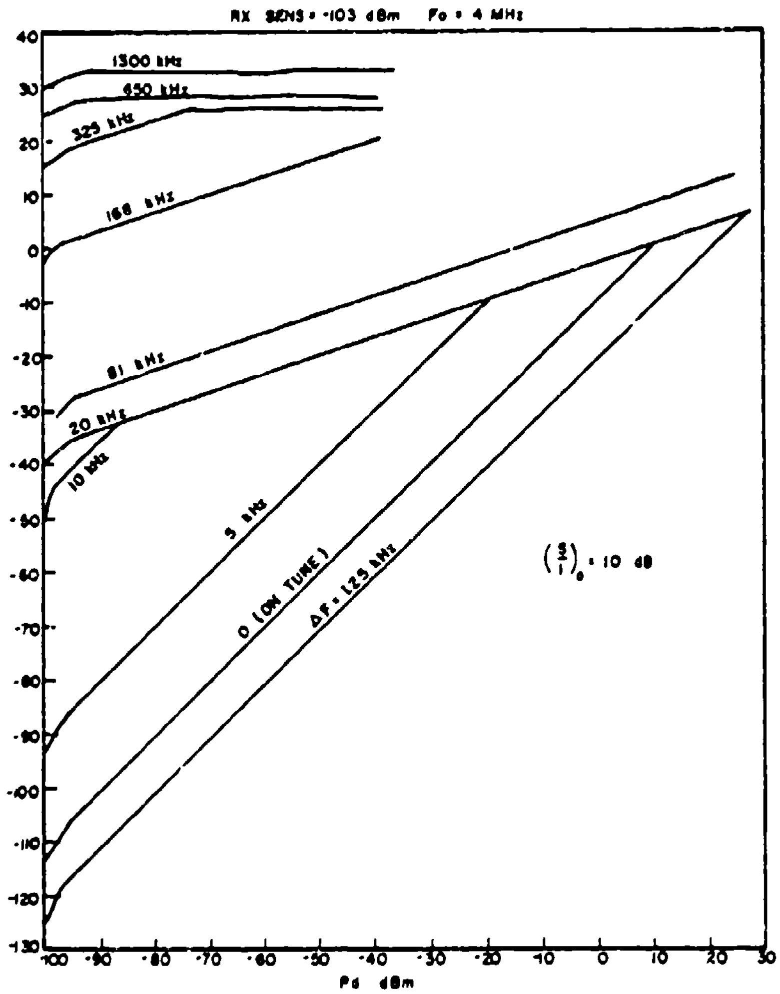

Figure D-4. Calculated adjacent-signal input levels for a standard response, bands 4 through 7 (includes AGC).

INTERMODULATION DATA

The intermodulation constants were computed as follows:

$$K_{m,n} = -(m+n-1)\,G_{2,0}\,(\omega_o) + B_1 - B_{m+n} - 20\log(m^2+n^2) - 20\log\left[\frac{(m+n)!}{2^{m+n-1}m!\;n!}\right] \qquad \text{(D-6)}$$

$$K'_{m,n} = -(m+n-1)\,G_1\,(\omega_o) + A_{1,0} - A_{m+n,o} - 20\log(m^2+n^2) - 20\log\left[\frac{(m+n)!}{2^{m+n-1}m!\;n!}\right] \qquad \text{(D-7)}$$

where

$K_{m,n}$ & $K'_{m,n}$ are conversion losses due to non-linear mixing;

$K_{m,n}$ losses are said to occur in the mixer;

$K'_{m,n}$ losses in the RF amplifier

m is harmonic number of one interfering signal contributing to receiver intermodulation response

n is harmonic number of the other interfering signal contributing to receiver intermodulation response

$G_1(\omega)$ is $20\log_{10} g_1(\omega)$, in $\mathrm{dB}\left(\frac{V}{\sqrt{mW}}\right)$

$g_1(\omega)$ is the ratio of the RF amplifier input voltage to the square root of the available power at the receiver input, a linear frequency-dependent transfer characteristics. Units are $V/\sqrt{mW}$

$A_{i,0}$ is value of the i^{th} order Taylor series coefficient of the RF amplifier with AGC below threshold conditions, computed by the pentode model (Reference 15).

COMPARISON OF PREDICTIONS WITH MEASURED VALUES

TABLE D-1 presents a comparison of predictions of SINAD for interactions involving the R-388. For these interactions, predictions fared slightly better than the overall average of all receiver interactions. One should not, however, conclude that theoretical prediction techniques are preferable to measurements. The problem is a many faceted one. For example, the BC-939B antenna coupler was not used with the R-388 receiver in any case. Mismatch loss uncertainty due to the model of this coupler was found to be a significant source of error in the other interactions.

TABLE D-1

COMPARISON OF PREDICTIONS WITH MEASUREMENTS FOR INTERACTIONS INVOLVING THE R-388 RECEIVER

Frequency Assignment	SINAD Errors (dB)	Bin Errors
I	4.68, 9.36	1, 2
II	1.00	0
III	-1.15	0
IV	2.03, 5.63	0, 1
V	5.30	1
VI	-7.62	2
VII	-.58	0
VIII	0.00, 0.00	0, 0
IX	2.87	1
X	2.34	0
XI	-.57, -2.05, -4.04	0, 1, 1
XII	No Prediction for this Assignment	
XIII	2.00, 2.00, 3.00	0, 0, 0
XIV	No Prediction for this Assignment	
XV	No Prediction for this Assignment	
XVI	No Prediction for this Assignment	
XVII	-8.06, -10.56, -6.00	2, 2, 1
XVIII	4.48, 5.34	1, 1
XIX	-9.23, -13.42	2, 3
XX	3.57, 11.17	0, 2
XXI	No Prediction for this Assignment	
XXII	No Prediction for this Assignment	
XXIII	6.46	2
XXIV	2.82	0
XXV	No Prediction for this Assignment	

Bin Errors	Number	Percentage
0	13	43.3
1	9	30.0
2	7	23.3
3	1	3.3
4	0	0.0
Totals	30	100.0

Probability Estimates: $P_{1C} = 73.3\%$

$P_{2C} = 96.7\%$

APPENDIX E

BC-939-B COUPLER ANALYSIS

A simple mathematical model for the BC-939-B coupler was incorporated in the ECAC TRACE program (Reference 9) in November, 1973. This model was found to have certain restrictions due to several simplifying assumptions used at the time. In particular, the frequency range over which the model was applicable was quite limited. Modifications that extend the useful frequency range have been made to the original model. This improved model is now part of the TRACE program.

The circuit diagram for the coupler in the technical manual[16] depicts the coupler in the 2-10 MHz tuning range as an auto-transformer (with leakage inductance = 1.6 μH) and a variable inductor (maximum value = 96 μH) as shown in Figure E-1.

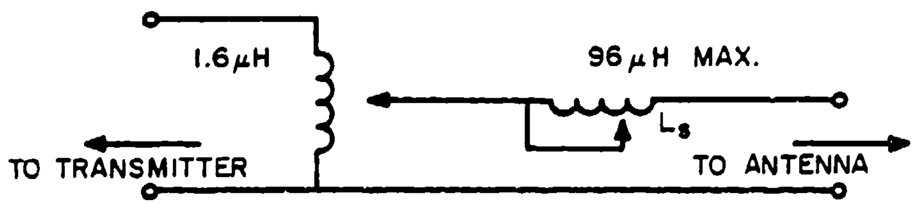

Figure E-1. BC-939-B coupler schematic for 2-10 MHz tuning range.

[16] Department of the Army Technical Manual, TM-11-809-35, "Radio Transmitters T-368/URT, T-368A/URT, T-368B/URT, and T-368C/URT and Antenna Tuning Unit BC-939-B Field and Depot Maintenance."

From photographs of the coupler in the technical manual, coil dimensions and spacing between turns of the coils were estimated[17]. The auto-transformer is assumed to have a non-unity coupling coefficient between the two sections of the auto-transformer. Although the coupling coefficient is generally a function of the position of the tap on the auto-transformer, a constant value of K = 0.3 was chosen. No significant changes in the calculated effects of the coupler were noticed in the TRACE calculation for other values of K near this value. A mathematical model to describe an auto-transformer with non-unity coupling coefficient is a network[18] as shown in Figure E-2.

$$M = K\, L_1\, L_2$$
$$L_a = (L_1 L_2 - M^2)/(-M)$$
$$L_b = (L_1 L_2 - M^2)/(L_1 + M)$$
$$L_c = (L_1 L_2 - M^2)/(L_2 + M)$$

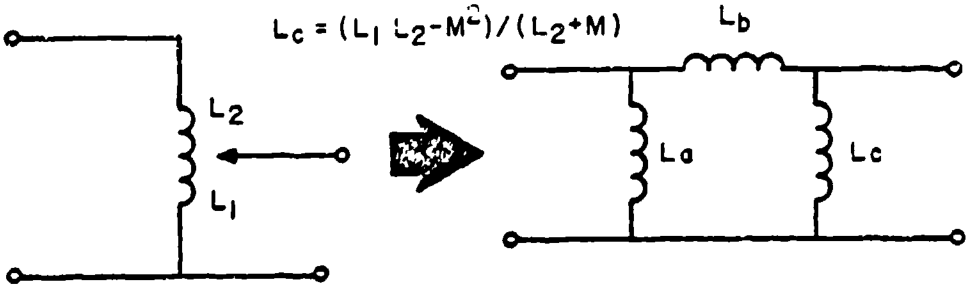

Figure E-2. Representations of actual BC-939-B autotransformer (left) and mathematical equivalent circuit (right).

Measurements performed on the BC-939-B coupler (Reference 5) indicated that stray capacitances would have to be considered. A null in the measured coupler characteristics in the region 15 to 20 MHz

[17] ECAC Memorandum by ACOP-C/Gawthrop, "Coil Dimension Estimates for the BC-939-B Antenna Tuning Unit (Coupler)," February 1975.

[18] Signatron Quarterly Progress Report 1 October 1971 to 1 March 1972, Contract No. F30602-70-C-00, "Communications Receivers Interference Modeling."

indicated a self-resonance in the coil L_s. Using the physical dimensions of the coil, a relationship was established between the value of the coil inductance used for tuning the coupler and the self capacitance of the coil. This relationship was derived using Medhurst's formulas for RF coils (References 14 and 19). Self capacitances were also estimated for the two sections of the auto-transformer. However, the auto-transformer leakage inductances cause resonances which are far removed from the tuning region of the coupler, and therefore have no effect. Parallel resistance values were calculated using Medhurst's formula for Q (Reference 14) and are included for all coils.

The presence of an SWR (standing wave ratio) meter at the input to the coupler places a 40 pF capacitance across the input terminals. This 40 pF was included, although no significant effect was noticed as a result of its presence in the model.

Output impedance measurements for the coupler indicate a fairly large capacitance across the output terminals (approximately 50 pF), which is explainable as capacitance between the coil L_s and the case plus capacitance associated with the output connector. Capacitance associated with a measurement probe is also a possibility.

Considering the non-unity coupling and all of the above capacitances, the model for the coupler in the 2-to-10 MHz tuning range was modified to reflect the equivalent circuit as shown in Figure E-3. For other tuning ranges, a capacitor was added in series with L_s, or a different coil with another series capacitor was used for L_s. Similar self capacitance is associated with this new coil and the same modeling techniques were used.

[19]Radiotron Designer's Handbook, 4th Edition, Chapter 11: "Design of Radio Frequency Inductors," 1952.

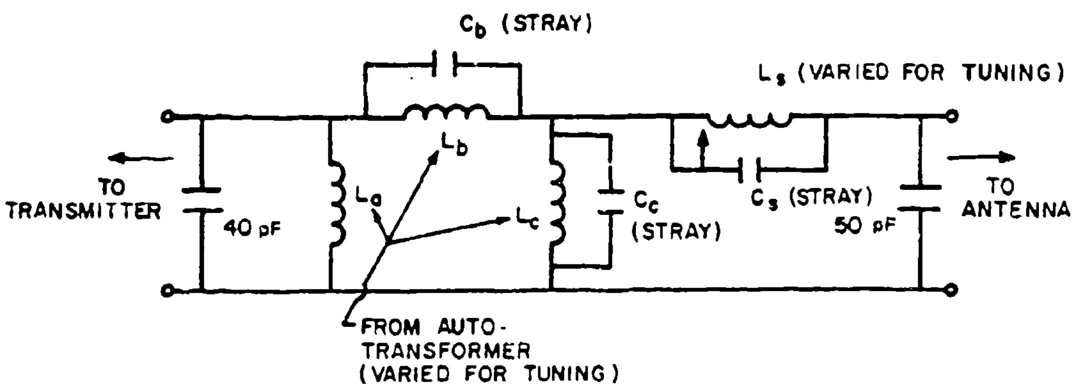

Figure E-3. Equivalent BC-939-B coupler schematic for 2-10 MHz tuning range.

The algorithm used for tuning the coupler model is similar to actual field tuning of the coupler. Values for L_s and the auto-transformer turns ratio are preset in the model. With the antenna impedance given, the input impedance of the coupler is calculated at the tuned frequency. L_s is then varied to minimize the difference between the input impedance, as calculated, and the value (50 + j0)ohms. The turns ratio is varied to further minimize the difference. This process is repeated for L_s, and alternately the turns ratio, until the magnitude of the difference is less than a given value or a fixed number of iterations has occurred.

Once all of the element values have been set by the tuning algorithm, the coupler input, output, and transfer impedances are calculated at all frequencies as required by the TRACE program.

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16. Department of the Army Technical Manual, TM-11-809-35, "Radio Transmitters T-368/URT, T-368A/URT, T-368B/URT, and T-368C/URT and Antenna Tuning Unit BC-939-B Field and Depot Maintenance."

17. ECAC Memorandum by ACOP-C/Gawthrop, "Coil Dimension Estimates for the BC-939-B Antenna Tuning Unit (Coupler)," February 1975.*

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